Chapter 6
Discussion and conclusion
6 Discussion and conclusion

6.1 Introduction

In the introductive chapter it is argued that knowledge sharing is crucial for New Product Development (NPD) consortia to make optimal use of the specialized knowledge present in participating organizations and to combine the knowledge into a new product. In practice professionals working in the NPD consortia have a hard time sharing knowledge effectively. As pointed out, existing literature sheds no light on how to enable knowledge sharing in the consortia. Taking four possible enablers as a starting point, this study aims to provide insight into how these enablers affect knowledge sharing within pairs of team members and within pairs of teams. Moreover, the research aims to contribute to the understanding of mechanisms underlying knowledge sharing relations within teams (intra-team level) and between teams (inter-team level). Finally, the study explores the differences between knowledge sharing at the intra-team level and at the inter-team level. By creating a multi-theoretical framework, we were able to explore the effects of the enablers and the theories’ explanatory values in an empirical study.

This chapter starts by highlighting the key findings of this research. Subsequently, the scientific and managerial implications of the findings are discussed in section 6.3 and 6.4, respectively. This chapter ends with a discussion of the limitations of the study and by making suggestions for future research in section 6.5.

6.2 Key findings

As far as the effects of the enablers on knowledge sharing are concerned, a key finding is that task dependency is the main enabler for knowledge sharing within teams. It enables team members to share knowledge more reciprocally, more frequently and on more content types. Co-location and expertise overlap also enable knowledge sharing between team members, but less strongly than task dependency. Being involved in multiple projects reduces the probability of team members sharing knowledge with others who are involved in a single project. However, when two team members are both involved in multiple projects they are more likely to share knowledge mutually, more frequently and on multiple content types.

In relation to the mechanisms underlying knowledge sharing relations within teams (intra-team level), the main finding is that Proximity theory has the most explanatory strength for the effects of co-location and expertise overlap. Furthermore the empirical findings indicate that the effects of project involvement are best explained by Social Exchange theory. For the effect of task dependency it is found that Proximity theory, Social Exchange theory and Transactive Memory theory equally explain the effects
that are found. Focusing on the knowledge sharing characteristics explained, we found that, overall, Proximity theory best explains knowledge sharing within teams. Transactive Memory theory was found to have added value in explaining the number of contents shared, whereas Social Exchange theory has added value in explaining the frequency of knowledge sharing between team members.

The findings at the inter-team level suggest that task dependency has a large enabling effect for the reciprocity and frequency of knowledge sharing between teams. For the number of content types shared between teams (multiplexity), task dependency was found to make knowledge sharing between teams more focused on one or two types. Expertise overlap and co-location also enable knowledge sharing between teams. Both appear to increase the probability of mutual and more frequent knowledge sharing. Between teams, a difference in overlap expertise seems to be related to multiple contents shared. Furthermore, support was found that co-location enables teams to share particular contents of knowledge (know-how and know-what).

For the mechanisms underlying knowledge sharing between teams, the key finding is that knowledge sharing between teams is highly demand-driven. The empirical evidence suggests that it is a combination of mechanisms as proposed by Transactive Memory theory and Proximity theory that shape the frequency and multiplexity of knowledge sharing between teams. No support was found for the premise that Social Exchange theory is applicable to knowledge sharing between teams.

Comparing the findings for knowledge sharing within and between teams, we found that at both levels task dependency has a large enabling role. For knowledge sharing at both the intra-team and the inter-team level it appears that co-location and expertise overlap are also enablers. Three main differences are found between the two levels of knowledge sharing. Firstly, task dependency leads to more content types shared within teams, but focuses knowledge sharing between teams. Secondly, expertise overlap within teams makes team members more likely to share knowledge mutually, but between teams it is found to negatively affect the reciprocity of knowledge sharing. Thirdly, where expertise overlap is found to result in a tendency to share multiple types of knowledge within teams, at the inter-team level it makes teams less likely to share knowledge of multiple content types.

A comparison between the levels of knowledge sharing on the theories explaining knowledge sharing shows that overall Proximity theory provides the most supported propositions. Between teams Transactive Memory theory has a larger role in explaining knowledge sharing than within teams. Whereas Social Exchange theory does have added value in explaining knowledge sharing within teams, between teams it does not seem to play a role.
6.3 Scientific implications

The overall contribution of this study to literature is threefold. It enhances the comprehension of how task dependency, co-location, expertise overlap and project involvement enable knowledge sharing within and between teams of large instrument consortia. Additionally, it contributes to the understanding of social theories explaining knowledge sharing in instrument consortia and the conditions under which knowledge is shared. Finally, it shows similarities and differences in knowledge sharing between team members and between teams, by comparing the intra-team level with the the inter-team level. This section discusses the scientific implications.

First of all, adopting a social network approach proved to be very useful for studying knowledge sharing. Even though most of the enablers included in this study are mentioned by other authors (Allen, 1977; Baughn, Denekamp, Stevens, & Osborn, 1997; Cummings & Teng, 2003b; Dougherty, 1992; Hamel, 1991; Hollingshead, 1998a; Nonaka et al., 1995; Szulanski, 1996; von Krogh et al., 2000), their effects were not yet directly measured. Certainly not within the context of instrument consortia, even though in both practice and literature they are perceived as strongly affecting knowledge sharing. The social network approach made it possible to study the effects of the enablers on knowledge sharing in this context, because it allows for direct measurement of knowledge sharing interaction between team members and between teams, respectively.

Secondly, our study proves that simultaneously studying multiple characteristics of knowledge sharing gives a more multi-dimensional picture than just focusing on one characteristic of knowledge sharing. Including multiple characteristics of knowledge sharing relations is not common in current literature. Using a social network approach for studying knowledge sharing is relatively new and in the cases where it is used, the research merely includes elementary characteristics such as the existence of a knowledge sharing relation or, in a few cases, the strength of the relation (Akgun et al., 2005; Cross, Parker, Prusak, & Borgatti, 2001; Hansen, 1999). Monge and Contractor (2003) conclude that network research in general “...focuses on relatively obvious elementary features of networks such as link density and fails to explore other, more complex properties of networks such as attributes of nodes or multiplex relations”. Our study does not just include the strength of knowledge sharing relations. The use of a social network approach enabled us to give a more multi-dimensional picture by including reciprocity and multiplexity as characteristics of knowledge sharing. Incorporating different characteristics of knowledge sharing proved to have added value, for the empirical results of this research show that there are differences among the knowledge sharing characteristics in how they are affected by the enablers. For example, we found that task dependency leads to more frequent knowledge sharing between teams, but also to less contents of knowledge shared. Additionally,
the empirical findings suggest that there are differences in mechanisms underlying the different characteristics of knowledge sharing. For example, within teams it is mainly the mechanisms as proposed by Proximity theory that explain the direction (reciprocity) in which knowledge is shared, and it is mainly mechanisms as proposed by Transactive Memory theory that explain the number of contents shared. This leads to the conclusion that studying knowledge sharing by including one characteristic only gives a partial view on knowledge sharing, and including multiple characteristics of knowledge sharing does have added value, for it gives a more multi-dimensional view.

Thirdly, this thesis shows that differences between different levels of knowledge sharing should be taken into account. In this thesis knowledge sharing is studied at two levels. Current literature on knowledge sharing mostly makes no explicit difference between different levels of knowledge sharing. In general knowledge models, authors make implicit assumptions that what plays a role in knowledge sharing within teams also plays a role in knowledge sharing between teams (McElroy, 2003; Nonaka et al., 1995; von Krogh et al., 2000). In articles on knowledge sharing one level of analysis is generally chosen, for example knowledge sharing within teams (Palazzolo, 2005), knowledge sharing between units of firms (Hansen, 2002; Tsai, 2001), or knowledge sharing between firms (Lam, 1997). Our empirical findings show that between the intra-team and the inter-team level there are differences in the effects of enablers on knowledge sharing characteristics. For example, whereas expertise overlap increases the number of contents shared between team members, it decreases the number of contents shared between teams. Furthermore, the findings suggest that there are differences between the intra-team level and inter-team level in the mechanisms underlying knowledge sharing. At the intra-team level the mechanisms of Social Exchange theory do seem to underlie knowledge sharing between team members, as some of the effects found could only be explained by Social Exchange theory. Between teams Social exchange theory did not have any explanatory value, implying that the mechanisms as proposed by Social Exchange theory do not seem to shape knowledge sharing between teams. These findings imply that it does not seem to be realistic to assume that mechanisms that play a role in knowledge sharing within teams are similar to mechanisms that underlie knowledge sharing between teams. When studying knowledge sharing, these differences should be acknowledged.

Fourthly, we found that using a multi-theory perspective is very useful in studying knowledge sharing. Using multi-theory approaches is not yet very common in studying networks or in studying knowledge sharing. Contractor, Wasserman and Faust (2006a) were, to our knowledge, the first to test multi-theoretical hypotheses on knowledge sharing networks. There are other authors that use a multi-theory model for explaining knowledge sharing, for example Watson and Hewett (2006). Watson and Hewett (2006) use two theories to explain the effectiveness of intra-firm knowledge transfer. They use social exchange theory to develop a model of factors that
impact the frequency of knowledge transfer. Expectancy theory is used to build a model of factors that lead to knowledge reuse. In doing so, they do not account for one phenomenon by combining the two theories, but use two theories to develop separate models for separate phenomena: a model for knowledge transfer and a model for knowledge reuse. We adopted a multi-theory approach more similar to that advocated by Monge and Contractor (2003). Our theoretical framework incorporates three social theories. From Proximity theory, Transactive Memory theory and Social Exchange theory propositions were formulated for the effects of the enablers on the frequency, reciprocity and multiplexity of knowledge sharing. Our empirical findings support the notion that using a multi-theory perspective to explain knowledge sharing is useful. By using a multi-theory approach, we were able to account for all of the effects found and to explore which social theory may have explanatory value and under which conditions. At the start of our research there was no single theory available to explain knowledge sharing within the context of NPD consortia. The social theories included in the theoretical framework made differential predictions about how the enablers would effect knowledge sharing. Not all of the predictions were differential, with contradictory explanations given by the social theories. Some of the predictions were similar, with complementary underlying mechanisms proposed by the theories. Our empirical findings suggest that there are multiple mechanisms simultaneously shaping knowledge sharing in instrument consortia. Not one of the theories could exhaustively explain the effects found, but by using multiple theories all of the effects found could be accounted for. This implies that in research where it is yet to be explored what theory might be applicable to the subject studied, and in research where one supposes that multiple mechanisms may play a role, the multi-theory approach seems to be useful.

Not only does the present study prove that a multi-theory approach is useful for studying knowledge sharing, but by contributing to the understanding of social theories explaining knowledge sharing in instrument consortia and the conditions for sharing knowledge it also prompts the development of a new theory for explaining knowledge sharing in new product development consortia. This is discussed in more detail below.

**Starting point for a new theory**

For intra-team knowledge sharing, the findings indicated that the effects of expertise overlap and co-location are best explained by Proximity theory. The effects of involvement in multiple projects are best explained by Social Exchange theory and the effects of task dependency were explained by both Proximity theory, Social Exchange theory and Transactive Memory theory. Figure 6-1 illustrates the explanatory value of the three theories for knowledge sharing within teams. From the results we concluded that in situations where the basic closeness between the team members is very low or variable, knowledge sharing between team members is not necessarily positively affected when they are more alike. In other words, the
mechanisms as described by Proximity theory do not apply under the circumstances in which the basic closeness varies or is low. One situation in which the basic closeness is particularly low is when team members are involved in multiple projects. Under these circumstances Social Exchange theory best explains knowledge sharing within teams. Comparing the theories on their affirmed propositions for knowledge sharing characteristics (figure 6-1B), the conclusion is that overall Proximity theory best predicts the knowledge sharing characteristics. This means that team members mainly approach each other on the basis of who is most proximate to them. Compared to Proximity theory, Transactive Memory theory mainly has added value in explaining multiplexity when the basic closeness varies (when team members are involved in multiple projects). This indicates that when the basic closeness varies or is low, team members base their knowledge sharing more on the perceptions they have of each other’s knowledge. This supports the conclusion above, i.e., that Proximity theory is less applicable under conditions with low basic closeness. Under these circumstances a team member just wants the knowledge he needs for the execution of his tasks. He will approach the person he thinks is expert and can give him the knowledge he needs, regardless of how proximate this person is to him. For frequency of knowledge sharing we found that exchange mechanisms as proposed by Social Exchange theory also play a role. This could indicate that for critical or specialty knowledge team members share knowledge with fellow team members who have the most appropriate knowledge, and closeness is less important.

These insights can be used as a starting point for a new theory explaining knowledge sharing within teams in NPD consortia. In this new theory, one can state that mechanisms of closeness underlie the reciprocity of knowledge sharing. In other words, team members prefer knowledge sharing with team members who are physically close, with whom they have a shared area of expertise, and with whom they are task dependent. Also, they tend to share knowledge mutually with team members who are close. For frequency and multiplexity of knowledge sharing, the new theory would explain knowledge sharing by the basic closeness of the situation and the extent to which a person needs specialist knowledge. Depending on the basic closeness and the extent to which specialist knowledge is required, mechanisms of Proximity theory or mechanisms of Social Exchange theory explain the frequency of knowledge sharing. When the basic closeness is relatively low or varies, team members share knowledge more often with other team members whom they perceive to have the knowledge they need and to whom they can offer knowledge in return. This mechanism also shapes the frequency of knowledge sharing when team members need critical or specialist knowledge. In situations where the basic closeness is relatively high, team members share knowledge more frequently with other team members who are proximate.
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Figure 6-1: Explanatory value of the theories for intra-team knowledge sharing

A: explanatory value in explaining the effects of the dyadic attributes

B: explanatory value in explaining the aspects of knowledge sharing

TM: Transaction Memory theory
SE: Social Exchange theory
Prox: Proximity theory

Figure 6-1: Explanatory value of the theories for intra-team knowledge sharing
The number of contents of knowledge shared (the multiplexity of knowledge sharing) is explained by a combination of mechanisms of Proximity theory and Transactive Memory theory. Team members share multiple contents of knowledge with other team members who they consider to be experts. Team members prefer experts who are proximate to them. It helps when team members are co-located, because then they are better able to identify expertise. But even when the basic closeness is low or varies and their expertise recognition may not be very accurate, they turn to team members who they perceive to be experts in the areas in which they need knowledge. These starting points for a new theory explaining knowledge sharing in NPD consortia are summed up in text box 1.

From the empirical research between teams we found knowledge sharing to be strongly demand-driven. This means that, in contrast to knowledge sharing within teams, mechanisms as proposed by Social Exchange do not seem to play a role (see figure 6-2). Teams that seek knowledge from other teams are not concerned with having any knowledge to offer in return. Thus, between teams Transactive Memory theory and Proximity theory have the most explanatory value for knowledge sharing. The reciprocity of knowledge sharing between teams is best explained by Proximity theory, as is the case with knowledge sharing within teams. It is mainly task dependency that determines whether teams share knowledge and in which direction they do so. Also we concluded that the frequency of knowledge sharing between teams is explained by a combination of mechanisms proposed by Transactive Memory theory and Proximity theory. Contrary to the intra-team level, where mechanisms of closeness as proposed by Proximity theory play an important role, Proximity theory seems to lose explanatory strength between teams. This can be explained by the relatively low basic closeness between teams. Teams are formed on the basis of their expertise and are regularly dispersed over a number of locations. Teams simply have less opportunities to base their knowledge sharing on what team is proximate. We found that teams mainly base their knowledge sharing on cognitive dependencies they perceive to have with other teams. Teams are cognitively dependent when they are dependent on each other’s knowledge. These dependencies are highly related to task dependencies. This indicates that mechanisms of Transactive Memory underlie knowledge sharing between teams. Findings also indicate that if it is possible, teams prefer to find the knowledge required in teams that are cognitively close. This indicates that mechanisms as proposed by Proximity theory also play a role. For multiplexity we concluded that similar mechanisms shape the number of contents shared between teams. The perception that teams have of the expertise of other teams is the most important for the number of contents of knowledge shared between teams. If teams are physically close, mechanisms of closeness also play a role. Teams will share more contents of knowledge with teams that are physically close.
### Starting a new theory for knowledge sharing in NPD consortia

<table>
<thead>
<tr>
<th>Basic closeness low or varies or Specialist/ critical knowledge is required</th>
<th>Basic closeness high</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within teams</strong></td>
<td></td>
</tr>
<tr>
<td>Team members prefer knowledge sharing with ‘close’ team members (reciprocity shaped by mechanisms of closeness)</td>
<td>Team members prefer knowledge sharing with ‘close’ team members (reciprocity shaped by mechanisms of closeness)</td>
</tr>
<tr>
<td>Team members share knowledge more often with whom they think they have knowledge and to whom they can offer in return (frequency shaped by exchange mechanisms)</td>
<td>Team members share knowledge more often with ‘close’ team members (frequency shaped by mechanisms of closeness)</td>
</tr>
<tr>
<td>Team members share more contents with persons they perceive to be experts (multiplexity shaped by expertise recognition)</td>
<td>Team members share more contents with ‘close’ team members</td>
</tr>
<tr>
<td><strong>Between teams</strong></td>
<td></td>
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<tr>
<td>Teams seek knowledge sharing with other teams they think have the expertise they need (reciprocity shaped by mechanisms of transactive memory)</td>
<td>Teams prefer (mutual) knowledge sharing with teams that are close in terms of task dependencies (reciprocity shaped by mechanisms of closeness)</td>
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<tr>
<td>Teams share knowledge more frequent with teams on which they are cognitively dependent and have the knowledge they need (frequency shaped by mechanisms of transactive memory)</td>
<td>Teams share knowledge more frequent with teams on which they are cognitively dependent and/or cognitively close (frequency shaped by mechanisms of transactive memory and closeness)</td>
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<tr>
<td>Teams share more contents with teams they perceive to have the knowledge required (multiplexity shaped by mechanisms of transactive memory)</td>
<td>Teams share more contents with teams they perceive to have the knowledge required and/or with the teams that are physically close (multiplexity shaped by mechanisms of transactive memory and closeness)</td>
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*Text box 1: Starting point for a new theory explaining knowledge sharing in NPD consortia*
It should be noted here that because of the demand-driven nature of knowledge sharing between teams, when mechanisms of Transactive Memory theory shape knowledge sharing, the processes of directory updating and information retrieval have the upper hand. Information allocation is less present.

The conclusions above can be taken as a starting point for formulating a new theory for explaining knowledge sharing between teams in NPD consortia. Teams have fewer opportunities to base their knowledge sharing on which team is most proximate. Nevertheless, there are situations in which teams seem to have a preference for sharing knowledge with teams that are proximate in task dependency, physically close or cognitively close. Under certain circumstances, teams do not really have a choice of ‘close teams’ because there are no ‘close teams’ or because ‘close teams’ do not have the specialist knowledge they need. In these situations, the teams will still share knowledge with other teams they perceive to have the expertise they need. In these situations distance does not play a role: if a team needs certain knowledge, it will get this knowledge because it is needed for the execution of its task(s). The starting points for a new theory at the inter-team level are summarized in text box 1.
6.4 Managerial implications

The main objective of this thesis is to explore the role of enablers in knowledge sharing in instrument consortia. In this section I take the liberty of freely interpreting and translating the empirical findings in terms of managerial implications.

For practical purposes one of the most important findings of our study is that knowledge sharing is indeed a process that can be enabled in the consortia. The empirical study shows that the enablers influence the way in which people in instrument consortia share knowledge. Considering the enablers and their effects on knowledge sharing, indications can be given of when to use which variable in order to influence the knowledge sharing characteristics. Textbox 6.1 gives an overview of the enablers and their role in knowledge sharing.

Based on the present study it is possible to give some practical guidelines on how to manage knowledge sharing in instrument consortia. A distinction is made between guidelines for the start-up phase of a consortium and guidelines for managing knowledge sharing during the NPD process. The guidelines differ because when starting up a consortium, decisions are made that create the context in which knowledge is shared. In the interviews held with team leaders and managers, it became clear that during the NPD process the managers have to deal with this context and anticipate the situations at hand. During the process it is not really possible for them to change the task dependencies, for example. Both situations are discussed below.

Starting up a project

In starting up an instrument consortium, the environment in which the professionals have to work and share knowledge is created. The most important implication of our research is that there should be awareness of which enablers play a role in how people share knowledge and what their effects are. We will illustrate three effects that the decisions made in the start-up phase of the project may have.

First, there are many dependencies between tasks of teams and between tasks of team members. Professionals have to share knowledge where these task dependencies exist. Our findings indicate that they do indeed share knowledge where they perceive task dependency. If they do not perceive task dependencies, the probability of their sharing knowledge is small. To have the professionals share knowledge where task dependencies exist, it is crucial for them to be well informed on the task dependencies that exist. So it is important that from the start of the project, the task dependencies are explicitly communicated to all professionals working in the consortium (at least the dependencies relevant to them).
**Effects of enablers on knowledge sharing**

**Co-location:**
- Facilitates knowledge sharing, both within and between teams
- Stimulates people to mutually share knowledge
- Increases the chance that people share knowledge more frequently
- Increases the number of knowledge contents shared

**Expertise overlap:**
- Facilitates knowledge sharing both within and between teams
- Makes people more likely to share knowledge
- Intensifies the frequency of knowledge sharing
- Increases the multiplexity of knowledge sharing within teams
- Makes knowledge sharing more focused between teams

**Task dependency:**
- Is the largest enabler of knowledge sharing
- Stimulates mutual knowledge sharing
- Increases the frequency of knowledge sharing
- Makes professionals within teams more likely to share knowledge on multiple contents
- Focuses the knowledge sharing between teams on one or two knowledge types

**Involvement in multiple projects:**
- The involvement of team members in multiple projects stimulates them to share knowledge on multiple contents
- The involvement in multiple projects stimulates mutual and frequent knowledge sharing with other team members who are also involved in multiple projects

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Second, one of the findings in our study was that professionals do not tend to spontaneously share knowledge, but mainly when they need knowledge. They rarely share knowledge because they think someone may be interested in their knowledge. However, a more active attitude may prevent some problems. Actively passing on knowledge enables professionals to better anticipate changes in the design, for example. This active attitude in knowledge sharing may be stimulated by creating awareness among the professionals that it is important to approach others when you think you might have useful knowledge for them. It may also help increase their awareness of the instrument they are working on and show them the chain of activities in the module. Often the bigger picture is clear to team leaders or managers, but this know-why is lacking on the level of professionals working in the teams. Showing the professionals in the teams the importance of the tasks they perform, and the relation their tasks have to the complete instrument, is likely to make them more aware of the importance of active knowledge sharing.

Third, at the beginning of a consortium decisions are made in selecting institutes, forming teams and picking who will be working on the project. Although these decisions are mostly based on who can make the
necessary investments, they have consequences for the differences in expertise. The development of an instrument requires different areas of expertise to be represented in the project. This is not only because the instrument has components that require different specialists, but also to stimulate creativity in the project. Therefore it is neither desirable nor realistic to advocate expertise overlap in all sets of team members where knowledge sharing is necessary. A possibility to create common knowledge in the consortium is to provide some sort of basic course on instrument development for everyone who participates in the project. It is also advisable that project management courses are offered to team leaders and managers in the projects. Team leaders and managers in the instrument consortia are often “best engineers” who are promoted to team leader. Their strong point is their excellent knowledge as regards content. Their level of project management knowledge varies. Offering team leaders and managers project management courses is likely to increase their awareness that they have an important role in monitoring and steering the process of their team. Also, the courses would help create common ground between team leaders. At the same time they would allow the team leaders to get to know each other better, which may be of use later in the project when they need each other for solving problems.

Fourth, knowledge sharing between teams mainly occurs through contact persons, and the expertise overlap can be taken into account when appointing these contact persons. Especially for teams where knowledge sharing among members is crucial, this can be done by appointing two contact persons who are expert in similar areas. Another possibility is to appoint separate contact persons for sharing knowledge with specific teams, in such a way that the contact persons who have to share knowledge have an overlap in expertise.

Fifth, selecting institutes and forming teams results in a certain degree of physical dispersion. Co-location is found to enable knowledge sharing. If this is a relevant variable in setting up a consortium, the consortium members should be aware of this. In some cases deliberate decisions can be made on who will be working co-located and who will not. Co-location may in some cases be impossible or too costly in the whole process of the project. In these situations it can be decided to co-locate people for a limited period of time or for a particular phase of the project, for instance at the beginning of the project, so that people get to know each other personally and learn about each other’s expertise. This will facilitate knowledge sharing over a distance in later project phases. Text box 3 summarizes the guidelines for managing knowledge sharing in the start-up phase of a consortium.
Guidelines for managing knowledge sharing in the start-up phase

- Be aware that the decisions made in this phase create the context in which people have to share knowledge during the NPD process.
- Be aware of the enablers that play a role in how people share knowledge, and the effects they have on knowledge sharing.
- Stimulate a more active attitude in sharing knowledge by placing the activities of the professionals in the perspective of the complete instrument they build.
- Explicitly communicate task dependencies between teams and within teams.
- Provide opportunities for acquiring common knowledge, for example by providing a basic course.
- Match contact persons for knowledge sharing between teams, where possible.
- Take deliberate decisions on (temporary) co-location.

Text box 3: Guidelines for managing knowledge sharing in starting up a project

During the NPD process

In managing knowledge sharing during a project, the most important is to be aware of the variables that play a role in the way people share knowledge and how this may affect knowledge sharing. Most circumstances are given by the setting of the project. If the enablers are not ideal, the team leaders and managers can anticipate this and manage the situation. For example, when a team leader knows that his team members are also involved in projects outside the consortium, he should be aware that this may have an impact on how they share knowledge. He should regularly monitor this knowledge sharing. Also in situations where the enablers are ‘ideal’, it is still no guarantee that knowledge sharing is optimal. Thus also when the enablers are ideal, the team leaders and managers have to actively monitor and manage knowledge sharing.

Monitoring knowledge sharing can be done in different ways. Talking to team members is an important source of information to monitor knowledge sharing within the team. The team leader could ask his team members regularly if they have regular meetings, for example, or whether they get enough information from one another and from the other teams, and evaluate whether the team meetings are perceived as useful. Another possibility, certainly when the team consists of a large number of people, he could use an instrument like social network analysis to monitor the frequency, reciprocity and multiplexity of knowledge sharing within his team. Monitoring knowledge sharing in the team enables the team leader to anticipate better. If he notices that two team members do not share knowledge frequently enough, for example, he can pro-actively respond by deciding to temporarily co-locate them. In this way the manager can actively anticipate the knowledge sharing to prevent problems. Being able to pro-actively manage knowledge sharing therefore not only requires awareness on the variables that play a role, but also requires monitoring knowledge sharing on a regular basis. This is necessary because the knowledge sharing characteristics may change over time. Also in different
phases in the project, different states/values of reciprocity, frequency, and multiplexity may be optimal.

When it is necessary to stimulate knowledge sharing between team members or between teams, in some cases the enablers can be used for influencing the reciprocity, frequency, and/or multiplexity of knowledge sharing. When using the variables to influence knowledge sharing between teams, the knowledge sharing characteristic one wants to influence should be carefully considered. Using an enabler to influence a knowledge sharing characteristic can simultaneously influence other knowledge sharing characteristics in an unintended way. For example, an overlap between task dependency and expertise enables mutual and frequent knowledge sharing but impairs multiplex knowledge sharing. This also implies that one should consider the whole repertoire of possible enablers and carefully weigh the effects and side-effects when one wants influence knowledge sharing.

Some enablers are easier to use for influencing knowledge sharing characteristics than others. Text box 6.1 summarizes the effects of enablers on knowledge sharing. Some suggestions on how the enablers can be used to influence knowledge sharing are given below.

Using the enabler task dependence for influencing knowledge sharing is not easy during the project. The original task structure is created for good reasons. Teams and team members are selected for tasks because of their expertise or because of more political reasons. These reasons are under pressure if the task dependencies are changed. Therefore it is not always possible to change task dependencies. When teams or team members are simply not aware of their task dependencies, this awareness can be created using task flow diagrams, for example, to clarify where task dependencies exist.

Enabling knowledge sharing by creating expertise overlap is somewhat limited during the project. During the project it may seem possible to shift tasks between team members. Nevertheless, this may be difficult because team members have already gained task specific knowledge. Also, it takes a lot of time when someone has to learn a new task and in some cases this is impossible because in-depth knowledge is missing. In some cases it may be possible to have two professionals attend a conference together or to have them (or one of them) take a course so they have some common knowledge overlap.

Co-location can be used as an enabler of knowledge sharing at any time in the NPD process. It is a relatively easy way to stimulate knowledge sharing. However, co-locating teams or team members can be quite costly, certainly if it is for long periods. Co-locating complete teams may also be not (financially) practicable. However, in most cases it will not be necessary to co-locate teams completely. For example, when in a certain phase of the development process it is very important that two teams share knowledge, it may be decided to co-locate some members of these teams for some weeks or months. And in some cases it may just be enough to get the team members or teams together more often in a temporary form of co-location.
To actively use *involvement in multiple projects* as an enabler for knowledge sharing is not very feasible. A team leader may notice that a team member who is involved in multiple projects does not share knowledge frequently enough or only asymmetrically with the other team members. In that case he may look into the option of not involving this team member in multiple projects anymore and have him/her work at the consortium only. Mostly this is not an option in actual practice. We also found that when two team members are both involved in multiple projects, they are more likely to share knowledge, to do this more frequently and on multiple contents. Nevertheless, if two team members do not share knowledge when they are both involved in this one project, it is not very plausible that they will start sharing knowledge when they are both involved in multiple projects. Perhaps the increased reciprocity, frequency, and multiplexity are a side-effect. It is likely that team members who have crucial knowledge are also involved in multiple projects. Then the team members in the consortium need them for their knowledge and therefore share knowledge with them very frequently. Another explanation is that team members who are involved in multiple projects also work together in these projects. This is a plausible explanation because the world of expertise in which these professionals find themselves is a small community. In conclusion, we would not advise to use involvement in multiple projects as a variable to enable knowledge sharing between team members, because the effects are not straightforward, not very strong and/or not statistically significant compared to the effects of the other variables.

The findings of the present study have one other important implication for managing knowledge sharing during the NPD process. An important finding for practice is that team members or teams in the consortia do not tend to spontaneously share knowledge but mainly when they feel the need to. The strong effect of task dependency indicates this, but it is also one of the main findings in our qualitative study of knowledge sharing between teams. Knowledge sharing is highly demand-driven. The emphasis is clearly on knowledge retrieval, whereas knowledge distribution or allocation is not so much the case. This has two implications.

First, this is probably the reason why knowledge sharing, especially between teams, is strongly focused on know-how and know-what. Know-why and know-who are only rarely shared between teams and spread through projects. Instrument consortia may benefit if these types of knowledge are shared more. The management of the consortia should consciously distribute know-why and know-how and stimulate the sharing of these types of knowledge for two reasons. (1) Know-why, because people then have more background knowledge about the project and understand why they are doing the things they do, what the importance of their part is and how their part relates to other parts. As shown, this perception of task dependencies is the main enabler of knowledge sharing. Sharing know-why is also crucial as it gives an overview of the distribution of task dependencies. (2) Sharing know-who is mainly important between teams. As our qualitative study showed for both projects, teams did not sufficiently
know which expertise the other teams had and which teams they could best approach for particular problems. Between teams knowledge sharing can be more efficient when teams directly approach those teams who have the relevant knowledge.

The second implication of knowledge not being spontaneously distributed or allocated through projects is that teams have a very reactive attitude in knowledge sharing. They only start to share knowledge when a problem is experienced. A more pro-active attitude in knowledge sharing is likely to prevent some of the problems experienced in projects. A pro-active attitude implies that teams actively distribute and allocate knowledge to other teams which they think have an interest in knowing. This requires that teams know what other teams are working on (know-why) and what knowledge other teams have and need (know-who). If the teams would actively distribute and allocate knowledge to other teams, they could anticipate situations better, manage the interfaces better (especially when making changes in their parts), but also reach synergy in foreseeing problems and reaching synergy in negotiations with third parties in buying parts, for example.

**Who should manage knowledge sharing?**

In managing the knowledge sharing within as well as between teams we point out the crucial role for team leaders and managers. Their insight into how members of their team collaborate and share knowledge and their leading role makes them very suitable for monitoring and managing knowledge sharing. For knowledge sharing between teams they have an important bridging (gatekeeper) function between their team members and other teams. They have to identify what information is important for other teams and what information their teams need from other teams. In addition to the team leaders, the project level management has an important role in managing knowledge sharing. They are often involved in starting up the project and they are largely responsible for spreading know-why and know-how throughout the project. Both the project level management and the team leaders can also act as role models for the professionals working in the consortium. They can show the professionals that it is ‘normal’ to share knowledge with others by taking an active role in this and setting the example.

However, we observed that at the project level, neither subsystem managers nor team leaders are (fully) aware of their crucial role in knowledge sharing and distributing know-why and know-who. We would recommend creating more awareness at this level, for example by including knowledge sharing as a topic in the project plan at the start of a new project, and by integrating knowledge management as part of their tasks.
Guidelines for managing knowledge sharing

★ Be aware of the variables that play a role in how people share knowledge, and the effects they have
★ Take an active, anticipating role in managing knowledge sharing
★ Evaluate knowledge sharing between and within teams on a regular basis
★ Before using an enabler to influence knowledge sharing, clearly have in mind the knowledge structure that is meant to be changed
★ Be aware of the side effects that the use of an enabler has on other knowledge sharing structures
★ Keep in mind the differences in mechanisms that shape knowledge sharing within and between teams and adjust the use of enablers to this
★ There are multiple enablers at hand for influencing knowledge sharing; one should choose from this repertoire based on which best fits the situation at hand
★ Create awareness on all organizational levels that knowledge sharing is important to stimulate a more active attitude in sharing knowledge
★ Keep in mind that the management and team leaders have a crucial role in managing knowledge sharing

Text box 4: Guidelines for managing knowledge sharing

The project management should also consider including relational promoters (Ritter & Walter, 2003) in the project. The role of a relational promoter would be to manage the interaction between teams, so that knowledge is shared efficiently and effectively. He would act as an intermediate between teams, having an overview of where knowledge should flow and whether knowledge flows frequently enough between teams. In this way he would support knowledge exchange. This person could also promote knowledge sharing in the consortium, emphasize the importance of knowledge management types of issues during the project, monitor knowledge sharing between teams and mediate if problems occur.

6.5 Limitations and directions for future research

The study that we conducted is exploratory in nature because not much was known about what variables could be used to influence knowledge sharing in instrument consortia and what theories can explain these influences and/or the knowledge sharing in these consortia. The current study contributes to science in a number of ways. From our study it appears that the use of multi theory approach, network perspective, and study on multiple levels are complementary. The multi theory approach, network perspective and multilevel study can be used simultaneously and go together quite well. Using a network approach also makes it possible to conduct a more thorough multilevel study in which a number of levels are included and directly compared. This study focused on knowledge sharing at the dyadic level, between two team members or between two teams. A social network approach also allows for studying knowledge sharing at other levels, for example studying complete networks of teams. By studying complete
networks of teams, more insight could be gained into gatekeeper functions, for example.

Concerning the multilevel study, an additional way of building on our findings is to include variables at the team level. In that way it is possible to explore what characteristics at the team level influence knowledge sharing between team members. We found that mutual knowledge sharing by team members can largely be explained by variance at the team level. This means that mutual knowledge sharing between two team members depends for a considerable part on the team of which they are a part. This also applies to the inter-team level; it may be of added value to explore whether project characteristics or team characteristics influence the way in which teams share knowledge. Nevertheless, the approach chosen for the study has limitations as well. First, the data we gathered was limited. We had to make selections because not all data was complete for many dyads. Perhaps if we had had more complete data, this would have given a more complete picture.

Second, only two consortia were included. Because of the number of teams and the dyads within the teams it was still possible to do a proper analysis. But the question is: Do the findings apply to other settings? The applicability of findings always depends on the context in which the study was conducted. The empirical data was collected in one sector (space science). This has implications for the external validity, because it is hard to assess to which extent the findings are influenced by the sector in which the projects took place. The question of applicability is even more to the point because data collection took place in two consortia where measurement instruments for space science are developed. Two consortia is a small sample. However, the organizational structure and culture of the consortia show similarities with consortia in other sectors. The consortia are characterized by multifunctional teams spread over several institutes and countries that have to conduct knowledge intensive tasks in a high tech environment. Consortia in the automotive, airplane or energy sector seem to have similar characteristics. But also projects in service oriented organisations, like hospitals, may have circumstances that are highly comparable to the instrument consortia. Therefore it is not unlikely that the findings from the current study also apply to consortia in other branches, where the circumstances are highly comparable to those in the instrument consortia. Still it is open for future research to explore whether the findings of our research apply to other settings.

Third, a point related to the previous issue is that in our analysis, we considered that dyads of team members are nested in teams. It should preferably also be taken into account that dyads of teams are nested in projects. Because the teams were studied in just two consortia, it was not possible to include this in the analysis.
Like other studies, this thesis raises new questions that are leads for future research:

**What is optimal knowledge sharing?**
As discussed in the practical implications, the empirical findings raise the question when mutual knowledge sharing is optimal, for example, or what frequency of knowledge sharing is optimal in a certain phase of the NPD process. It is not possible to make statements like "the more frequent knowledge is shared, the better it is", or "mutual knowledge sharing is optimal", based on the current study. What knowledge sharing is optimal is likely to depend on the situation, the performance aimed for and the phase of the project. There are studies that indicate teams always need a minimum frequency of communication, and at the same time too frequent communication can impair the creative performance of a team (e.g. Leenders et al. 2007). Our recommendation for future research is to explore whether these findings can be translated to knowledge sharing, focusing on questions such as: what knowledge sharing characteristics are desirable in what phases of the NPD process?

**How do knowledge sharing relations develop over time?**
Knowledge sharing relations are dynamic and change over time. This thesis gives insight into the mechanisms likely to underlie knowledge sharing and how enablers shape knowledge sharing. It does not cover how the relations change over time and what happens when the enablers are used to intervene in knowledge sharing. It would be of great value if the changing nature of relations are included in future research.

**Is it possible to develop one unifying theory for knowledge sharing in instrument consortia?**
Chapter four and five set out conditions under which the theories explain knowledge sharing within and between teams. Section 6.3 formulated starting points for a new theory for explaining knowledge sharing in instrument consortia. The theories are very similar in scope, as they were selected on criteria based on the scope of our study. The theories are to some extent complementary in their explanations for knowledge sharing. Our answer is therefore that it seems possible to develop one unifying theory for explaining knowledge sharing. The current study only made a start for a new theory. It is up to future research to further study how the theories should be unified and to validate the new theory. Before unifying the theories, it should be explored to what extent the mechanisms proposed by the theories actually take place. We tested three theories on their propositions for the effects of enablers on knowledge sharing characteristics. For some enablers the theories propose the same effect and when this effect is supported by the empirical data. That was the case for the effects of task dependency, for instance. Our study could not answer the question whether it is all three mechanisms simultaneously shaping knowledge sharing or whether it is one of the mechanisms and as a by
product the propositions of the other two are also supported. Furthermore, the difference in bringing and retrieving knowledge was not measured. Future research should make this difference, because this difference is clearly made in the mechanisms included in these theories. A more qualitative approach, as used for studying knowledge sharing between teams, is well suited to gain these insights.

*Is the current thought line in product development literature useful*?

In current product development literature, decomposition intends to diminish task dependency by decomposing in such a way that there are as less task dependencies as possible. In the current study, empirical findings indicate that from a knowledge sharing point-of-view this line of thinking may not be advisable. By reducing task dependencies, professionals in the instrument consortia feel less need to share knowledge. It is up to future research to shine a light on this question.