The Engagement between Knowledge Transfer and Requirements Engineering

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Developing requirements in the early phase of product development is a process that poses considerable challenges. The most significant challenge is how to effectively transfer knowledge-related requirements. This paper highlights the challenges related to knowledge transfer practices, while developing requirements through a review of literature and an analysis of high-tech company interviews. The most significant challenges and their effects on practices are also discussed. We found that the roots of any difficulty in requirements transfer were embedded in the failure to transfer knowledge-related requirements and facilitate communication between stakeholders. This difficulty affects stakeholders' common understanding. Therefore, interpretations of the requirements vary and do not match the stakeholders' intentions. Lastly, the final requirements and specifications sent are unclear and ambiguous so the requirements need to be changed and modified.

Keywords: knowledge, knowledge transfer, requirements engineering, challenges

Introduction

The indicator of the success of a product is a product design that can truly meet the target set. To achieve that, we need to be able to find and specify the product requirements correctly and clearly base them on the customers', users', or other stakeholders' expectations. These processes are called requirement engineering and involve the front-end activities and main stage for developing any new product (Hall, Beecham, & Rainer, 2002; Nuseibeh & Easterbrook, 2000). The quality of execution of the front-end activities and the creation of well-defined product requirements play a critical role in a product's success (Cooper & Kleinschmidt, 1991). Well-defined product

requirements lead to clear understanding of the development work, including development time and cost, technical expertise required, market potential, etc., and help to avoid development slowdowns, unexpected project costs, and the creation of unsuccessful new products (Zirger & Maidique, 1990).

Requirements engineering involves communication among various groups of people relevant to the products, so the actual needs can be specified correctly. Requirements are considered an output of the early stage of product development and, at the same time, the input of the developmental stage for the actual production of the product. In the requirements process, many problems and challenges arise since the stakeholders have different points of views, leading to controversy. Therefore, stakeholders and developers must work collaboratively to effectively exchange potential information and knowledge for the requirement process. However, the knowledge transfer is never simple because certain needs, information, or knowledge are difficult to specify objectively. Knowledge-related requirements encompass tacit knowledge, which is highly personal and difficult to communicate to others, and explicit knowledge, which is formal and systematic and easy to communicate and share. Furthermore, the requirements themselves are not directly tangible and knowledge about them is mostly tacit. Therefore, transferring requirements to others is very challenging. Naturally, if the company fails to specify the needs or requirements correctly as proposed by all relevant groups, the new product launched tends to fail. Many previous studies show that products launched fail in the market because of an incomplete requirement process and a lack of effective requirement engineering management, rather than due to technical factors (Alves, Pereira, Valença, Pimentel, & Andrade, 2007). To sum up, when communication or knowledge transfer is not effective, all relevant information and knowledge of the product requirements are sent to the receiver incompletely. Therefore, transferring information, knowledge, intelligibility, and any view regarding products between the stakeholders and developers is crucial.

Currently, although many studies have been conducted on requirements engineering, few have specifically explored the issue of knowledge transfer in the requirements engineering process in the context of collaborative product development. Therefore, this research is an effort to bridge this gap by studying transferring knowledge, especially tacit knowledge-related requirements transfer, to understand the challenges that influence the knowledge-related requirements in the requirement engineering process.

The problems, obstacles, and potential issues found from this research are presented so that the transfer of requirements knowledge can be improved and requirement development can be furthered effectively with the lowest rate of production errors to help avoid costly and ill-informed project
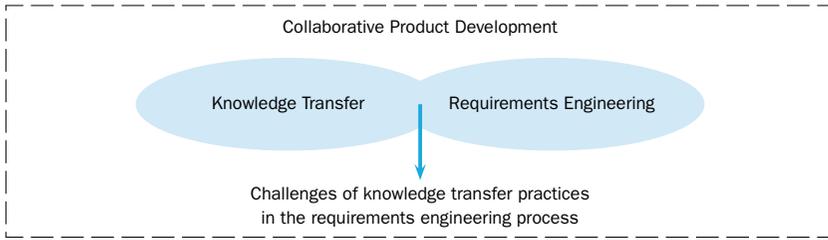
Figure 1 Theoretical Framework

decisions. To achieve the objectives of this study, the following research questions must be answered:

RQ1 What is the initial list of challenges in knowledge transfer and requirements engineering engagement?

RQ2 What is the importance and engagement of these challenges in high-tech company practices?

This paper is organized as follows. Section 2 presents an overview of the theory and previous studies in requirements engineering and knowledge transfer; this section ends with the theoretical synthesis. A research process is described in Section 3. The results are discussed in Section 4 and a summary of this research is concluded in Section 5.

Theoretical Foundations

This research bases its theoretical foundation on requirements engineering and knowledge transfer (Figure 1). Selected theories are applied to the extent required to identify the potential challenges that affect the transfer of knowledge requirements, especially tacit knowledge requirements transfer.

Requirements Engineering

Requirements Engineering Process

Requirements engineering is a core process of product development concerned with understanding stakeholder needs, identifying what the company intends to build, and ensuring product development builds a product that satisfies those needs at a minimum cost and rate of time (Kauppinen, Vartianen, Kontio, Kujala, & Sulonen, 2004; Asghar & Umar, 2010). Many stakeholders are involved in the requirements engineering process, including users, engineers, and developers. They participate in requirements and cooperate with each other. Requirements engineering is divided into development and management.

Requirements development deals with discovering, analyzing, and documenting requirements (i.e., Leffingwell & Widrig, 2000; Pfleeger, 1997;
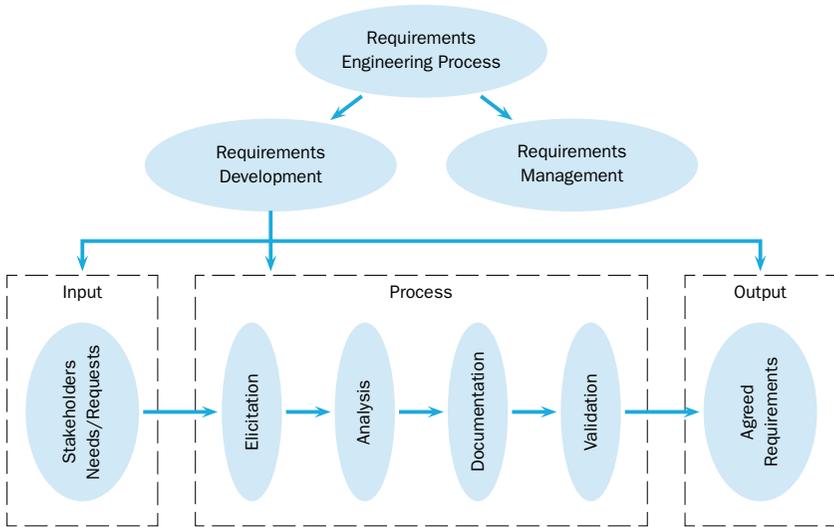
Figure 2   Requirements Engineering Process

Sommerville, 2004; Sommerville & Sawyer, 1997; Wiegers, 2003). The purpose of the output of requirements development is the product requirements documents. Requirements development can be further divided into elicitation, analysis, documentation, and validation processes. These processes are interwoven and there is a great deal of iteration and feedback from one process to another.

- *Elicitation.* The process of discovering and identifying requirements by communicating with stakeholders who will be affected by the system and who have a direct or indirect influence on the requirements (Sommerville & Sawyer, 1997). Many techniques are used: questionnaire surveys, workshops, scenario-based techniques, interviews, etc.
- *Analysis.* The process of analyzing the initial set of requirements and negotiating among different stakeholders to decide which requirements to accept since conflicts, overlaps, omissions, and inconsistencies which have to be resolved, will inevitably arise.
- *Documentation.* The development of a document that clearly and precisely records each requirement to enable communication.
- *Validation.* The final process of requirements development checks that the requirements accurately represent the needs of the system, which are consistency, completeness, and correct information (Pfleeger, 1997; Sommerville & Sawyer, 1997).

Managing requirements is a parallel process to other requirements engi-

neering processes (Sommerville & Sawyer, 1997; Kotonya & Sommerville, 1998). Even when requirements are specified, they are likely to be changed at least once during development and can be changed immediately after development. Therefore, requirements must be managed throughout the product development process. Managing requirements then helps to ensure that iterative and unanticipated changes are maintained throughout the development process.

Requirements

Requirements are identified during the early stages of product development as specifications of what should be built. Many researchers have provided a definition of requirements. Lawrence (1997) suggests a requirement is 'anything that drives design choices.' *Webster's Ninth New Collegiate Dictionary* (1989) defines a requirement as 'something required; something wanted or needed,' whereas Kotonya and Sommerville (1998) define requirement as 'a statement of a system service or constraint.' They are descriptions of how the system should behave, application domain information, constraints on the system's operation, or specifications of a system property or attribute. Therefore, a requirement is a necessary attribute in a product or system defined before design development. A requirement must be determined and agreed upon by the customers, users, suppliers, and other product stakeholders. Requirements are very important because they are used as an input in the design phase of product development. On the other hand, they provide the basics for all the development work that follows.

Challenges of Requirements Engineering

The most important step in successful product development is creating the requirements expected by the customers and stakeholders in the early phase. However, the process of developing requirements poses considerable challenges. Some of the most significant challenges of requirement development are ambiguity and incompletion (i.e., Curtis, Krasner, & Iscoe, 1988; Kotonya & Sommerville, 1998; Lubars, Potts, & Richter, 1993; Raatikainen, Mannisto, Tommila, & Valkonen, 2011; Wiegers, 2003; Zagajsek, Separovic, & Car, 2007). The requirements can be interpreted alternatively, which makes them incomplete and negatively affects product development afterwards. Ambiguity and incomplete requirements result from poor communication, which can have various causes (Bubenko, 1995; Damian, 2007; McAllister, 2006; Naz & Khokhar, 2009), for example, the lack of a standard knowledge transfer process followed by everyone. In addition, the ability to communicate the needs and interpretation among stakeholders are also important factors affecting the process (Sommerville, 2004). Tacitness can affect stakeholders' understanding and interpretation because it

is difficult to transfer or express to others (Pilat & Kaindl, 2011; Raatikainen et al., 2011). Differences in the stakeholders' knowledge level and skills or a supplier's lack of knowledge about the work process and technology affect the requirements development process, and are very challenging (Kauppinen, 2005). Many researchers found that the main problems in developing requirements are the lack of technical skills, the lack of understanding of the software and the product line being worked, and the lack of a writing requirements skill (i.e., Alves et al., 2007; Kauppinen, 2005; McAllister, 2006).

Time constraints pose another crucial challenge when developing requirements. Normally, in developing a product, the time spent is very constrained (Alves et al., 2007). Everyone has to compete with the time allowed so the product is launched within that time frame. This can lead the developer to make many mistakes. However, developing requirements is complicated work that requires a lot of time to ensure communication with every relevant person.

A limited time frame can lead to many mistakes. For example, some meetings that require experts' participation may not be run as expected because the experts do not have enough time to participate. Assigning a substitute to participate in the meeting can cause problems in understanding the work and eventually affect the entire work process. Communication among stakeholders is important as well. Sometimes, contact through email, telephone, or video conference is not effective. In-depth communication such as face-to-face communication is needed to build personal relationships and trustworthiness among stakeholders, which can ensure the work goes smoothly and effectively. Therefore, numerous researchers agreed the most significant challenge affecting the quality of requirements is how to effectively transfer knowledge-related requirements among stakeholders throughout the development life cycle.

Knowledge Transfer

Knowledge transfer is to pass knowledge from one person to another who needs that knowledge. Szulanski (1996) observed knowledge transfer as a communication model in which the transfer process can be viewed as *a message flow* (process) from *a source* to *a recipient* in *a given context*. In the transfer process, the characteristics of the senders and receivers play an important role. People who have great skills and a willingness to absorb and share knowledge achieve knowledge transfer results. Successful knowledge transfer also depends on the degree of the relationships between the senders and the recipients. The closer the personal relationship, the more efficient the transfer. Additionally, the characteristics of the knowledge and transfer methods are also important (Distanont, Haapasalo, Rassamethes,
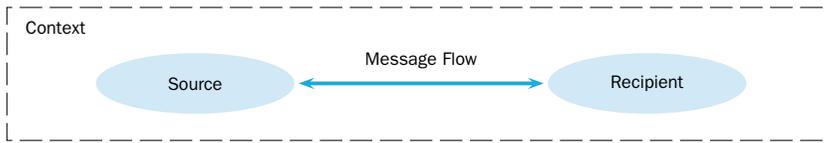
Figure 3 The Transfer Process (adapted from Szulanski, 1996)

& Lin, 2012). Each method of knowledge transfer is suitable for each specific situation depending on the type of knowledge to be transferred and the transfer method (Distanont et al., 2012). Some transfer methods are suitable for some types of knowledge but not for others. Therefore, classifying the knowledge to be transferred is useful and many researchers have classified the types of transferred knowledge. For example, Polanyi (1962) and Nonaka (1994) distinguished knowledge as tacit and explicit, whereas some researchers categorize knowledge as declarative (know-that, know-why, or know-when) and procedural (know-how) (Cohen, 1991; Huber, 1991; Kogut & Zander, 1992). According to the nature of knowledge transfer discussed above, the basic elements of a transfer should be *the source, the message, the recipient,* and *the context.*

Knowledge Transfer in the Requirements Engineering Process

The aim of the requirements engineering effort is to understand the characteristics of the software or system to be developed, and the desired results of the requirements engineering effort are documented requirements or specifications (Kotonya & Sommerville, 1998; Macaulay, 1996; Pfleeger, 1997; Sommerville & Sawyer, 1997; Zave & Jackson, 1997). In this process, the important problem is transferring requirements knowledge among stakeholders (Coughlan & Macredie, 2002; Gacitua et al., 2009; Raatikainen et al., 2011). The entire requirements engineering process is related to transferring knowledge, but the failure of requirements development is specifically caused by the transfer of knowledge-related requirements during this process. In the context of requirements engineering, knowledge transfer involves transferring needs, understanding, insight, information, and knowledge between stakeholders and developers to develop requirements. Close interaction and collaboration between stakeholders and developers are very important during requirement development since they have to exchange views and ideas or share information and knowledge necessary to effectively accomplish the requirement engineering work. During the requirements engineering process, knowledge related to the requirements has to be elicited and captured by using appropriate methods and during requirements development, tacit knowledge-related requirements are

created or captured. The knowledge gained through this activity needs to be transferred to others to create a requirement or specification in the end. One of many problems is that it can be difficult to transfer knowledge that is not explicit between stakeholders and developers. People may know how to do something but are unable to articulate how they do it. Furthermore, the requirements themselves are not directly tangible and knowledge about them is mostly tacit. Therefore, transferring knowledge to others is very challenging. Poor knowledge transfer during the requirements engineering process results in severe problems in later stages of product development.

Challenges of Knowledge Transfer

Although companies recognize the advantage offered by effectively transferring knowledge within and across organizations, many challenges affect successful knowledge transfer. The amount of research in the past confirms the importance of the nature and characteristics of knowledge; they can truly affect the process. In particular, tacit knowledge is very difficult to transfer (Albino, Garavelli, & Schiuma, 1999; Argote & Ingram, 2000; Gupta & Govindarajan, 2000; Nonaka & Takeuchi, 1995; Szulanski, 2003; Zander & Kogut, 1995). The degree to which knowledge is tacit influences knowledge transfer results through its impact on knowledge ambiguity (Simonin, 1999). Some researchers claim that to be able to transfer tacit knowledge, we need to adjust tacit knowledge to be explicit knowledge first. Therefore, many researchers have tried to implement an information technology (IT) method for adapting tacit knowledge to explicit knowledge before the transfer. However, some researchers have stated that we cannot make tacit knowledge explicit as expected and complete. Therefore, the attempt to adapt the type of knowledge mentioned is not appropriate, because certain parts of the knowledge will be lost. A possible effective way to transfer tacit knowledge is through personal communication. Tacit knowledge, as we can see, is an individual's knowledge and skill that require direct communication for the transfer. Knowledge may also be transferred by observing an expert so that we can understand that person's tacit knowledge from his or her on-job activities. Furthermore, the knowledge type is also needed to find the appropriate transfer channel.

However, Dixon (2002) indicated that knowledge transfer is not a compulsory voluntary action. An efficient transfer, therefore, depends on the willingness of senders and receivers to share. Moreover, the level of knowledge and skills of the sender and the receiver affect the knowledge transfer process. Efficient knowledge transfer necessitates the strong disseminative capacity of knowledge senders. It is the ability of senders to efficiently and effectively codify, articulate, communicate, and teach knowledge to other people (Tang, Mu, & MacLachlan, 2010). When the sender is not skilled

in communicating precisely what he or she wants to transfer, good transfer of knowledge will not happen, or if knowledge senders do not have sufficient ability to transfer needed knowledge to recipients, the knowledge to be transferred might be misunderstood, misinterpreted, and distorted. The efficiency and effectiveness of the knowledge transfer will be significantly reduced as a result, although the sender's capacity is necessary but not sufficient to facilitate full understanding of the knowledge transfer (Tang et al., 2010). The absorptive capacity of the receiver also plays a key role. Absorptive capacity is the ability to recognize and value new external knowledge, the ability to assimilate it, and the ability to commercialize it (Cohen & Levinthal, 1989). If the receivers cannot understand the knowledge transferred due to a lack of sufficient prior related knowledge to assess the value of that knowledge, the transfer fails as well (Argote & Ingram, 2000; Cohen & Levinthal, 1989; Gilbert & Cordey-Hayes, 1996; Hutchins, 1995; Ndlela & Du Toit, 2001). The disseminating and absorptive capacity depends on each person's prior knowledge level. Apart from the potential, knowledge, and skill level of the sender and the receiver, trustworthiness and motivation issues can also affect the success of a knowledge transfer (Dixon, 2002; Szulanski, 2000). If neither trusts each other or lacks motivation, creating an effective transfer is impossible.

In addition to the factors related to senders, receivers, and knowledge, relationships and interactions between the sender and the receiver are also worth considering (Distanont, Haapasalo, Kamolvej, & Meeampol, in press; Sverlinger, 2000; Szulanski, 1996; Zander & Kogut, 1995). The level of relationship between the knowledge sender and the receiver affects the difficulty of transferring the knowledge as well. Many previous works indicate that personal relationships affect the effectiveness and time used in transferring knowledge (i. e., Gupta & Govindarajan, 2000; Hansen, 1999; Kogut & Zander, 2003; Szulanski, 1996). For example, regarding tacit knowledge, direct communication between the sender and the receiver can ensure the transfer is conducted effectively. Therefore, we need to provide face-to-face communication in formal and informal settings because it can help increase personal ties, which can drive the knowledge transfer to be both faster and easier. However, the issue of cultural and language differences must be borne in mind.

Theoretical Synthesis – Challenges for Knowledge Transfer in Requirements Engineering

Based on the literature analysis in Chapter 2.2 about knowledge transfer, there are four basic elements of a transfer: source, recipient, message, and context. To fully understand the process of knowledge transfer in the requirements engineering process, understanding the criteria that affect a
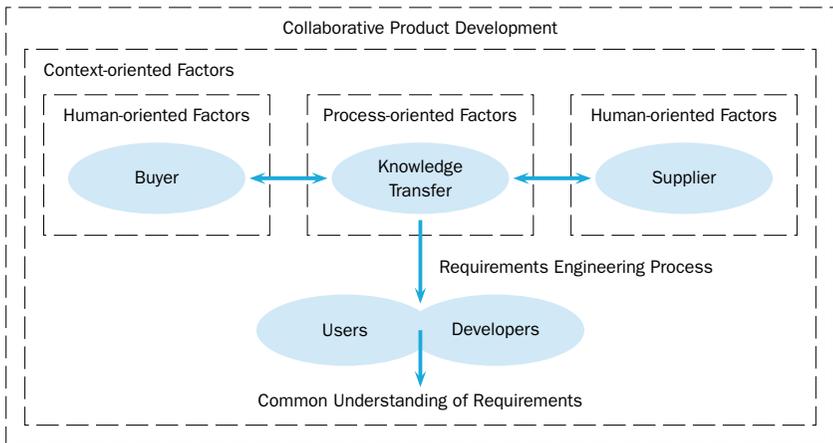
Figure 4   The Classification of Challenges in Transferring Knowledge During
the Requirements Engineering Process

transfer during requirements engineering knowledge is important. In this
research, we classified the challenges of knowledge transfer and require-
ments engineering by using a basic element of the transfer as a criterion.
The source and recipient are both people who have a role in sending and
receiving knowledge. Therefore, these two elements should be classified in
the same category – the human category. The message element is some-
how relative to the media and channel of knowledge transfer. It defines
how to transfer knowledge from a source to a recipient – the process cate-
gory. Additionally, the context element is about the environment which has
an impact on the transfer – the context category. This element can sup-
port the knowledge transfer or create barriers to transfer practices. There-
fore, according to these basic elements of a transfer, the classifications of
challenges have been grouped into (1) human-oriented factors, (2) process-
oriented factors, and (3) context-oriented factors.

The challenges in knowledge transfer and the requirements engineer-
ing process are summarized in Table 1. This synthesis highlights the key
findings from the literature review and previous studies. The goal of this
summary was to list all the challenges in the knowledge transfer and re-
quirements engineering process.

Research Process

The research was conducted as a case study: knowledge transfer in the re-
quirements engineering process was studied in a high technology company.
This case company offers complex telecommunication solutions, including
hardware, software, and services. Solutions are produced in cooperation

Table 1 Knowledge Transfer and Requirements Engineering Challenges

Knowledge transfer challenges	Requirements engineering challenges
Human-oriented factors	
KT1.1 Disseminative capacity of sender	RE1.1 Skill for defining requests/requirements
KT1.2 Absorptive capacity of recipient	RE1.2 Skill to understand and translate requests/requirements
	RE1.3 Articulating needs/requirements of potential stakeholders
KT1.3 Relationships between sender and receiver	RE1.4 The individual's relationship
KT1.4 Trust	RE1.5 Trust
KT1.5 Knowledge distance between sender and receiver	RE1.6 Different perspective and knowledge background (users and developers exhibit differences in language, experience, ambition, knowledge and interest)
KT1.6 Communication style	RE1.7 User-developer interpersonal communications
KT1.7 Motivation	RE 1.8 User involvement
Process-oriented factors	
KT2.1 Nature of knowledge to be transferred	RE2.1 Ambiguous requirements
KT2.2 Transfer channel	RE2.2 Inadequate channeling of requirements change information/knowledge
KT2.3 Different language	RE2.3 Communication channels for requirements knowledge to travel between stakeholders and developers
	RE2.4 Transferring requirements information/knowledge
	RE2.5 Lack of well-defined or standard process
	RE2.6 Time constraints
	RE2.7 Lack of opportunity to seek out relevant knowledge
Context-oriented factors	
KT3.1 Executive support/commitment	RE3.1 Executive support/commitment
KT3.2 Culture distance/diversity	RE3.2 Culture distance/diversity
	RE3.3 Distance between stakeholders

with partners and subcontractors. The case company has long traditions of continuous collaborative product development and has been developing the requirements engineering process for years. The main data collection method is interviews. Interviewees include nine persons that, at that time, were working in the same large product development project. The intervie-
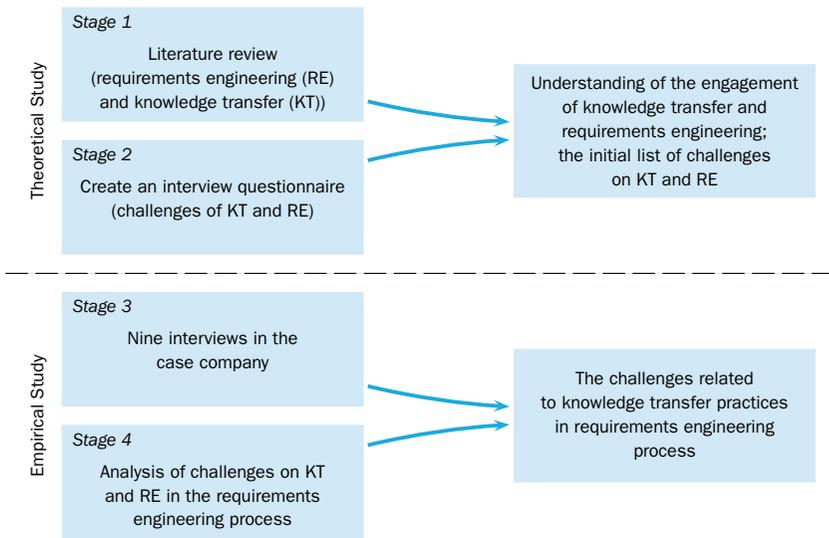
Figure 5   Research Process

wees represent different roles in the project. More detailed research process is presented in Figure 5 and in the following text.

Stage 1

The first stage involved an extensive literature review to understand the engagement between knowledge transfer and requirements engineering and explore the challenges of knowledge transfer and requirements engineering.

Stage 2

The second stage involved creating the interview questionnaire based on the literature review. The interview questionnaire consist of three parts. The first part is rating the initial list of challenges. In this phase, the informants rate each challenge in the Likert scale from 1 to 5 to express a) the criticality of the challenges and b) the current performance of handling these challenges (i.e. how well the challenge is tackled currently). The second part is designed to highlight the challenges affecting the process of transferring requirements to the supplier in practice. The particular viewpoints are requirements engineering and knowledge transfer. The final part is designed to discuss other challenges in practices, which are not included in the initial list.

Stage 3

This phase involved the interviews at a case company, which is a high-tech company in Finland. In-depth interviews were conducted with nine represen-

tatives. The interviewees were selected carefully on the basis of their professional background and expertise. Four of the interviewees were project managers, three interviewees were specialists, and two interviewees were technical managers. Their experience and current interests ensured high motivation among the participants and up-to-date knowledge with respect to the topics discussed. The total work experience of those interviewed was typically between 10 and 20 years. The aim of the interviews was to identify the challenges of knowledge transfer and requirements engineering in practice. The interview consists of three parts: 1) to ask the participants to give a rating to the listed challenges, 2) to ask participants to explain how the challenges manifest in practice and their importance, and 3) to ask about any potential additional challenges that arise in practice.

Stage 4

The final stage involved analyzing the interview's results. The collected data from part 1 of the interview questions was analyzed via the gap analysis method. The NVivo program was used to analyze the data collected from part 2 and part 3 of the interview questions. Gap analysis (Franklin, 2006) is a tool that helps compare the gap between two things (Franklin, 2006); for example, actual performance with potential performance. In this research, gap analysis was conducted to measure the gap between the actual criticality and performance of challenges (the value of criticality minus the value of performance). NVivo is a qualitative data analysis computer software package, which helps with classifying, sorting and arranging data. In this research, this analysis method was useful to extract meaning and insight based on the data collected from the interviews.

Analysis of the Challenges Affecting Knowledge Transfer Practices

This section presents the challenges affecting knowledge transfer practices as found by the empirical study.

The Importance of Challenges

Based on the gap analysis, the challenges affecting knowledge transfer practices were identified (Figure 6). They were classified into four groups, ordered from the largest gap between the value of criticality and performance to the smallest gap. The first two groups of challenges are significant challenges. They are located in the most important area above the keep band. This area represents the challenges that are critical, but whose performance is poor in practice. The third group consists of the challenges lying within the band that reflect criticality commensurate with their performance. The fourth group are the challenges located below the keep band, a placement that indicates high performances deemed noncritical.
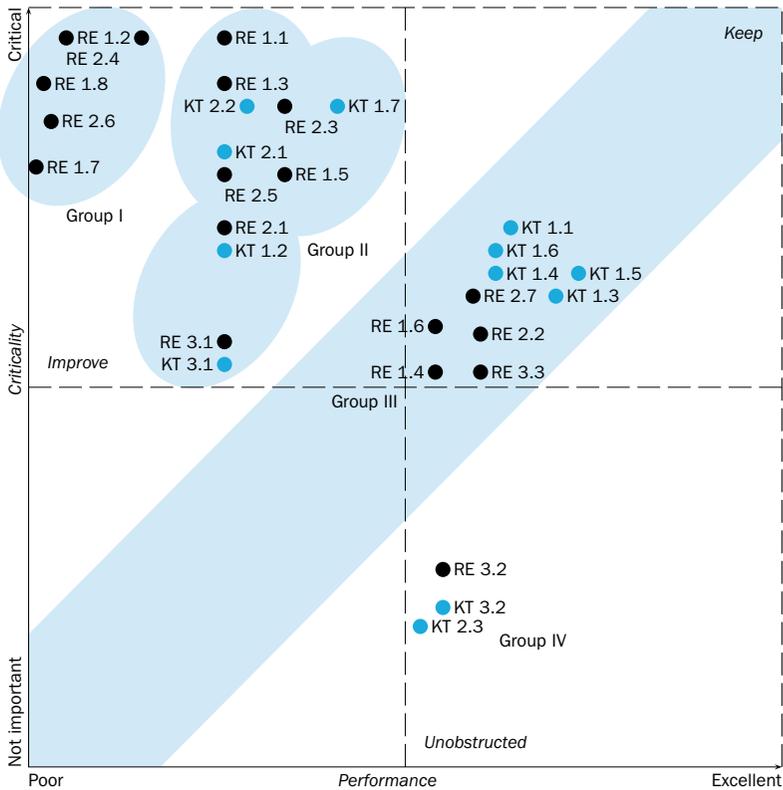
Figure 6   Challenges of Knowledge Transfer and Requirements Engineering

The challenges in groups I and II, which are located in the improvement area, are displayed in Table 2.

According to the analysis, which is based on the NVivo program, the importance of the challenges has been summarized in the following paragraphs. We also highlight additional challenges, i. e., the challenges described by the practitioners, but not mentioned in the initial list of the challenges based on theory.

Challenges in Group I

RE 1.2 Skill in understanding and translating requests/requirements. This skill seems to be not only very important, but also very challenging in the development of requirements. The challenge results from a different level of this skill between stakeholders and the supplier's lack of technical knowledge. Although the development team uses the same language and there is no need to translate anything, problems still exist. Moreover, if requests or requirements need to be translated, the outcome should be checked by

Table 2 Challenges of Requirements Transfer in Practice

Challenges in group I	Challenges in group II
Human-oriented factors	
RE 1.2. Skill in understanding and translating requests/requirements	RE 1.1. Skill in defining requests/requirements
RE 1.7. User-developer interpersonal communications	KT 1.2. Absorptive capacity of recipient
RE 1.8 User involvement	RE 1.3. Articulating needs/requirements of potential stakeholders
	RE 1.5. Trust
	KT 1.7. Motivation
Process-oriented factors	
RE 2.4. Transferring requirements information/knowledge	KT 2.1. Nature of knowledge to be transferred
RE 2.6. Time constraints	RE 2.1. Ambiguous requirements
	KT 2.2. Transfer channel
	RE 2.3. Communication channels for requirements knowledge to travel between stakeholders and developers
	RE 2.5. Lack of well-defined or standard process
Context-oriented factors	
	RE 3.1. Executive support/commitment
	KT 3.1. Executive support/commitment

both companies by a person who understands the translated language and this is very time-consuming.

RE 1.7 User-developer interpersonal communications. Having person-to-person communication is much better than communicating via email or telephone. It helps the individuals to understand each other more easily. However, this type of communication is not easy to facilitate, because there is not enough time for efficient communication between users and developers in addition to budget limitations of face-to-face communication between stakeholders.

RE 1.8 User involvement. It would not be a problem, if at least at the very beginning of requirements development, technical personnel or appropriate people with adequate experience, technical expertise, and language skill on the buyer and supplier sides were available to discuss and lead the requirements work. However, in practice, the supplier does not have enough human resources to solve all of the problems inherent in requirements work.

RE 2.4 Transferring requirements information/knowledge. This seems to be a crucial issue during the requirements development phase and other phases of product development work. There are many causes which gener-

ate difficulty. First, there is no clear guideline for transferring knowledge to the supplier; for example, a guideline on who is responsible for transferring the requirements to the supplier and how much information or knowledge should be transferred to the supplier. Second, the requirements or knowledge cannot be made explicit enough before being transferred. The next issue is that requirements have to be tailored a little bit before being transferred to the supplier; therefore, problems and misunderstandings occur. Finally, the requirements are not transferred to the correct person or actual users.

RE 2.6 Time constraints. There is no adequate time to create and analyze the requirements because the project timeline is not supported in daily work and business decisions come very late. Therefore, the time constraints constitute a risk and generate pressure to do everything in the requirement development process. This problem can create errors and be costly not only in the requirement engineering process, but also for the overall project.

Challenges in Group II

RE 1.1 Skill for defining requests/requirements. Requirements are not always clearly defined or detailed enough. Additionally, developers often use a kind of copy-paste requirement; therefore, there is a gap in the level of understanding between the product management team and the person who is defining the products.

KT 1.2 Absorptive capacity of recipient. This is a challenge for both sides: the supplier and the buyer. On one hand, the supplier does not understand what developers from the buyer side are communicating due to a lack of technical knowledge and variations in the capacity level. The buyer, on the other side, does not clearly understand the information, knowledge, or requirements transferred to the supplier.

RE 1.3 Articulating needs/requirements of potential stakeholders. This is a crucial factor. Sometimes stakeholders are uncertain about what they want or what they are doing. This issue leads to difficulty in expressing needs, requirements, or even problems.

RE 1.5 Trust. Trust affects how people work together. It also influences stakeholders' willingness to communicate openly, to transfer any knowledge, and to support one another. Sometimes people do not follow through with their commitment or fail to complete work on a certain schedule. This situation leads to a lack of trust. In addition, in some cases, developers cannot trust outsiders, such as suppliers or their own factories at other sites, because of information leaks. This issue leads to blocking the transfer between two parties.

KT 1.7 Motivation. Motivation is at a low level at the present; therefore, it has a negative impact on the performance of joint development with the supplier.

KT 2.1 Nature of knowledge to be transferred. Knowledge includes everything around the product and evolves all the time. It is very challenging to transfer and some knowledge related to requirements is not easy to express or transfer to other stakeholders. It is necessary to recognize the different types of knowledge and to determine the appropriate channels for transfer.

KT 2.2 Transfer channel and RE 2.3 Communication channels for requirements knowledge to travel between stakeholders and developers. Transferring information and knowledge through an electronic system (email or telephone) or documentation is not enough. Some issues are important and need to be discussed immediately or need to be discussed in more detail, for which the personal interaction is appropriate. Although face-to-face meetings are best for discussing and transferring information and knowledge, there are some limitations, such as travel bans. Another difficulty is that some types of knowledge, for example, approved requirements, modified requirements, full product definitions, or up-to-date information-related requirements are not automatically available to the supplier and the supplier cannot access the database. It is therefore not easy to obtain the latest documents or knowledge-related requirements.

RE 2.1 Ambiguous requirements. Ambiguous requirements cause misunderstandings and different interpretations. Sometimes developers do not realize that the requirements are not completed or even try to make them complete.

RE 2.5 Lack of well-defined or standard process. This issue creates trouble when working with the supplier. There are two main difficulties. First, there is no clear process for transferring the requirements to the supplier. Second, too many processes are either ineffectively or badly implemented; therefore, it is not easy to follow those processes.

RE 3.1 and KT 3.1 Executive support/commitment. Executive support and commitment are important in the sense that a business case is backed up with a realistic project plan. However, the current challenge is the lack of executive support, at least at the practical level, and sometimes the commitment of upper-level management is unclear.

Challenges in Group III

Most of the factors in this group relate to the human-oriented factor, especially different levels of knowledge and relationships between the buyer and the supplier. Different perspectives and knowledge backgrounds can create obstacles to collaborative working. They can lead to misunderstandings among stakeholders and consume much more time in terms of discussing and reaching a common understanding. In addition, relationships are an important factor in joint development. The closer the personal relationship, the smoother the work. A bad relationship can block interactions and destroy trust among stakeholders. However, according to the findings, although the

challenges in this group are very important, they can be handled. Maintaining continuous treatment is necessary for these challenges; otherwise, they can become a problem.

Challenges in Group IV

The factors in this group are cultural and language differences. These factors are not a problem and are even important, since people understand that differences occur between cultures and are willing to learn about another culture. Furthermore, culture diversity sometimes should be a benefit because of the variety of viewpoints.

Additional Challenges

In the last part of the interview, the informants were asked about any additional challenge that seems, in their view, to be crucial in the practices but was ignored in the initial list of challenges. According to the findings, four additional challenges were found. The criterion for summarizing these challenges is that at least five to seven informants mentioned them. Original quotations from the interviewees are written in italics in the following text.

Experience of organization. According to the interviews, most informants stated that their company is not experienced at working with a third party. '*Our management is expecting from our suppliers more efficient product creation than we can do ourselves. That is the main problem at the moment.*' The management level made a decision to collaborate with the suppliers, even though they did not have enough knowledge about how to select a supplier and how to manage operations with it. In addition, there was a lack of knowledge concerning the suppliers the company started to work with. There was also a lack of experience on the supplier side. '*Some suppliers are small companies so they don't have the history and they don't have this knowledge built in*' and '*There is one project that has been delayed a lot. This project must been completed in 12 months according to the agreement but because of the lack of experience of supplier this project has taken almost two years, and it's not ready yet.*' Some suppliers that the case company collaborates with do not have sufficient experience in product development. To conclude, the lack of experience is a challenge on both the buyer and the supplier side.

Experience of management. One of the current challenges in the case company is that there is a lack of people in the middle and top management who have practical working experience with product development projects or who have managed a project from the beginning. '*The management doesn't have the experience of product development. In the middle and top management, we don't have anybody that has done any project from the beginning to the end.*' '*There are new managers who don't understand the third party*
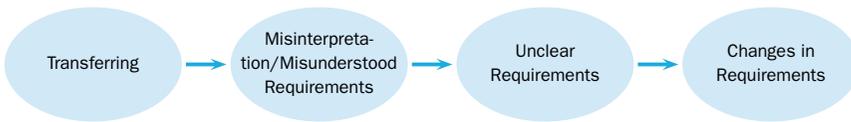
Figure 7   The Engagement of Knowledge Transfer and Requirements Engineering

and the nature of product development.' Thus, there are managers who are lacking a complete view, and they do not sufficiently understand the supplier and product development process. This impacts their ability to make effective decisions in the present situation. Eventually, this difficulty directly affects the requirement engineering process and product development.

Implementation of processes. Based on the interviewees, it seems that there is a lack of well-standardized processes for requirements engineering. 'We don't have a clearly established process of how to deliver the requirements to the third party.' As a result, the case company may not have a standardised process for requirements engineering. In addition, another challenge arises because the relevant people do not follow the process provided. 'In the general R&D or requirements engineering process, we don't follow the process.' It seems that there are mixed views on whether the case company has a well-standardized process for managing RE with suppliers. Despite the existance of a standard process or not, the implementation of processes poses a challenge.

Company internal process. According to the interviewees, another challenge comes from the case company's internal processes. The interviewees stated that it is difficult for the suppliers to adapt its processes to the buyer company's agile development. 'The way we work with the third party is very challenging and I think it will be very difficult for the third party to adapt to our agile development. An agile system is quite complicated' To conclude, the complexity of agile development is causing challenges for suppliers to adapt and to collaborate with the case company.

The Engagement of Knowledge Transfer and Requirements Engineering

In the earlier chapters, we explored knowledge transfer and requirements engineering challenges and how they manifest in the practices of a high-tech company. In this chapter, we will offer conclusions about how these challenges interrelate. This analysis was performed based on the findings from both literature and our empirical study. We discovered that the problems with knowledge transfer causes challenges in the interpretation of requirements to be transferred. This leads to unclear requirements and consequent changes in requirements. Figure 7 presents a summation of the causes and effects when there are problems in knowledge transfer.

Transferring. The transfer process is the problem itself in the case company because there is no clear guidance for knowledge and information transfer as well as the proper level of quantity and scope of knowledge to be transferred to the supplier. Moreover, the type of knowledge to be transferred also causes problems in the transfer process. Tacit knowledge is the most difficult type of knowledge to be transferred. It requires a high level of communication between the buyer and the supplier. Though the best way of communicating to transfer tacit information is face to face, this rarely happens. In many cases, the buyer and the supplier are located far away from each other. There can be also limitations in travel budgets. Furthermore, there is the issue of each worker's communication skills and level of knowledge. Hence, as we can see, explicit knowledge is considered much easier to transfer since it can be done through documentation, email, and databases. However, certain types of explicit knowledge are not easy to transfer, such as source code, which is impossible to send via email and, hence, requires another channel. The communication channel is another crucial issue in transferring requirements because each type of knowledge and information needs a different communication channel. Previous studies found that a company facing the problem of transferring information through the existing database faced the difficulty of the supplier being unable to access the information. In addition, the current requirements cannot be updated and thus the supplier has incomplete information. Adjusted requirements cannot be sent to the supplier promptly.

Misinterpretation/misunderstood requirements. This kind of challenge is caused by the requirement transfer process. Without good communication, the knowledge or information obtained can never be complete and causes misunderstanding and misinterpretations among stakeholders. In addition, due to the supplier's lack of skills and technical knowledge, they do not understand what has been sent by the buyer. However, this problem is caused by the buyer: the information they sent is not complete, because the requirements process is not complete. In addition, the buyer who sends the requirement cannot understand the requirements clearly and sends unclear requirements to the supplier-although even when the information was clear, the lack of skills in the requirements process could serve as an obstacle in the transfer process as well.

Unclear requirements. Once a misinterpretation occurs between the buyer and the supplier, the wrong knowledge is obtained, which leads to subsequent development of incomplete requirements. In addition, time limitations, such as when the requirements must be rush transferred, also contribute to incomplete requirements. Finally, when the requirements processor is not the person who implements the requirements, the patterned requirements are not accurate.

Changes in requirements. When the developed requirements are not accurate, they must be changed. Though the point that requires change may be minuscule, it may consume a lot of time, which can affect the entire project development process. In addition, if the business decision to start the project comes late, the requirements that have been developed need to be changed, and people who have joined in that development need some time to recognize what they did before. These difficulties affect the entire project schedule.

Based on the analysis of challenges in the case company, the authors found that the context is not the problem; the problem seems to be in the process and the real understanding of what should be developed. Challenges emerge from the process and the competency or expertise of the people involved in the product's development. However, clearly classifying requirements can improve this situation and mitigate the transfer difficulty.

Discussion and Conclusions

A high-tech company faced significant challenges in transferring requirements during the development process. These challenges may cause the failure of the project. In order to avoid development failure, it is necessary to know what those challenges are, and based on this information, means or solutions can be developed to overcome those challenges. The objective of this research is to understand the knowledge transfer and requirements engineering process and clarify the challenges of knowledge transfer practices in the requirements engineering process. In order to understand and explore these challenges, we have studied them both through literature and empirical research.

Based on literature reviews, the challenges can be classified into three groups: human-oriented, process-oriented, and context-oriented. These initial challenges have led to surprising findings about the similarity of the challenges of knowledge transfer and requirements engineering (see Table 1). By focusing on the initial list of challenges, the majority of challenges in human-oriented group can be clarified as not only relative to the ability to interpret, communicate, and understand the knowledge to be transferred, but also to relationships and trust between people. The majority of challenges in the process-oriented category are related to the mechanism of transferring knowledge between people, including the type of knowledge to be transferred and the transfer channel. The initial lists of challenges in the context-oriented group are related to support from the management level and the culture issue.

Based on the empirical evidence, we can synthesise that the majority of the process-oriented factors are important to improve, since they are critical but poorly performed. Human-oriented factors are critical but the

performance is at a good level, as even these are seen as critical, and the company can manage these as required and/or needed. Context-oriented groups are not seen as critical since the challenges in this group could not create any difficulty and their performance is at a good level. In addition to the importance of the challenges, engagement of these challenges was found. Difficulties in requirements transfer may result from failures in communicating requirements knowledge among stakeholders. These deficiencies in communicating requirements will weaken the common understanding. Nevertheless, the interpretations vary and do not always match the original intentions. At the end, this will cause changes in requirements. This situation will have a negative impact on the time and cost required for the project.

When evaluating this study, it should be noted that the empirical material for this study was collected only from one case company. However, the case company has been developing requirements engineering process for a long time and it can be considered a suitable case to interpret challenges in the requirements engineering process. The performance related to each challenge is probably case-dependent. However, the list challenges and their criticality may be more widely generalizable. The collected data in this research included the views of experienced informants who have been performing collaborative product development for several years and they are experts in this area. The obtained results provide value for the scope of this study. However, future research should study more case companies and more knowledge transfer practices for organizational interfaces. Moreover, the means and solutions for overcoming these challenges, as well as ways to facilitate effective requirements knowledge transfer, should be studied.

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