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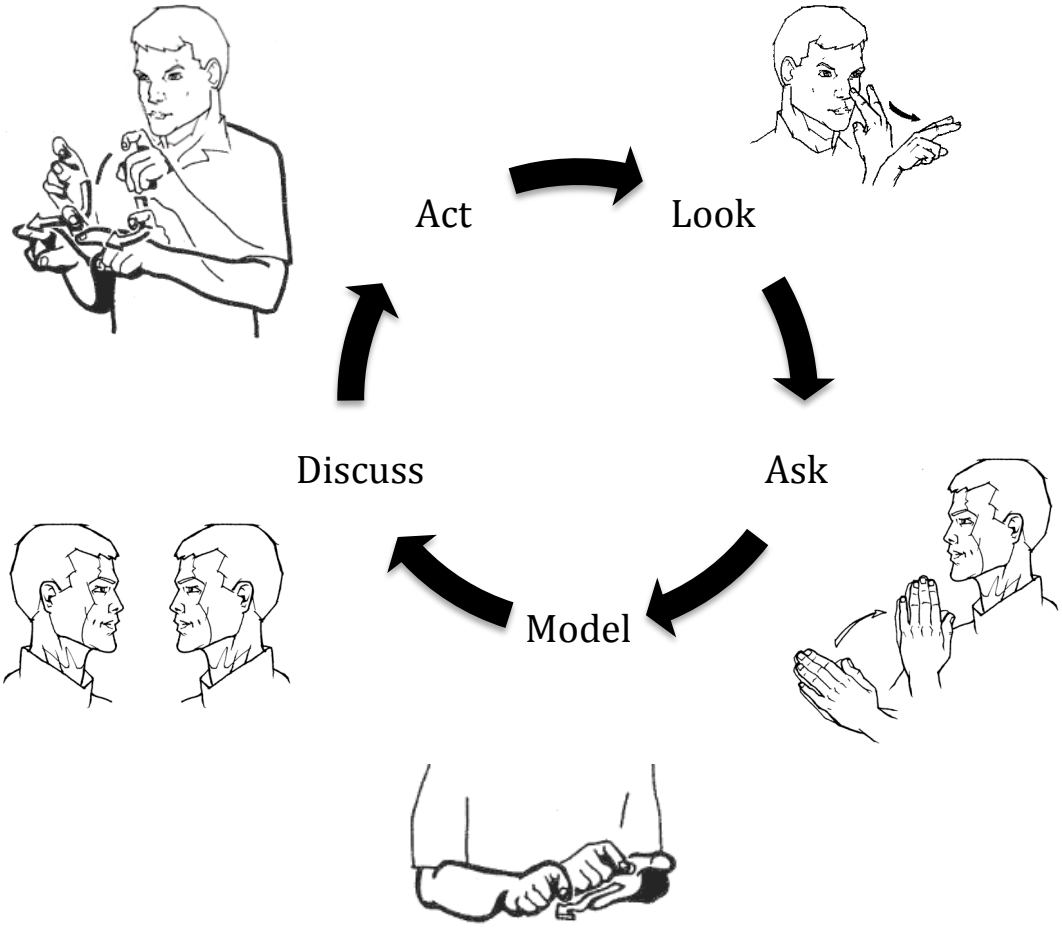

LEAN KNOWLEDGE REUSE

Analysis of Knowledge Reuse Patterns in Product Development

Master of Science Thesis

JONAS LANDAHL

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Lean method LAMDA (adapted from Holmdahl, 2010)

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Abstract

Due to globalization and high expectations of customers and users, the market for large technology-driven companies is fierce. Typically, product development efforts in large enterprises involve solving problems through fallback solutions on a daily basis, which may push any inconveniences forward. These inconveniences may occur in different organizational departments while employees desperately try to work towards customer and user needs and wants, who generally are difficult to formulate since the needs and wants may be unspoken.

Yet, in large enterprises, product development projects are traditional in its approach, which imply that the market input is vaguely defined as well as proposed and shared along the organization hierarchy. The knowledge reuse routines between organizational departments, and between projects, are traditionally scattered. These phenomena indicate an apparent difficulty to avoid making mistakes already encountered and learnt from somewhere else within the organization. For example, it can be constituted of "reinventing the wheel" or that each project writes the same "lessons learned". Due to the dilemma of neglected knowledge reuse efforts, it is intriguing to verify or contradict literature, as well as identify critical mechanisms for knowledge reuse in product development, in order to focus the attention on the company's most valuable resource – knowledge.

Hence, this paradigm has been challenged while constituting a case study at a large technology-driven enterprise, dependent on its product development efforts. The case study employs additional substance for identifying critical mechanisms for prosperous knowledge reuse, and if there are certain methods that are more, or less, suitable for knowledge reuse in product development.

From this study it can be verified that a traditional approach is applied at the company. Essentially, this large enterprise seems to struggle in their approach towards prosperous knowledge reuse between departments and projects. When considering knowledge reuse methods, it does not seem to be "one method fits all". What determines which method to apply, is typically the knowledge transferability. If a method is wrongly determined in-line with the transferability, it will be difficult to process and codify the knowledge, thus knowledge may be wasted. In this sense, it is important to consider what knowledge future users will need. Likewise, it is equally important, when the standards are set, to determine the transferability of the knowledge and choose a suitable method for the purpose

In this study context, the critical mechanisms for prosperous knowledge reuse has shown to include:

- Standard methods saturating all organizational departments, for ensuring low subjectivity
- Easy structure of codified knowledge, typically with illustrations and short describing text
- Plan the process of codifying knowledge
- Engage time into the codifying of knowledge

- Rethink and reflect upon codified knowledge
- Establish easy locating systems for high availability of knowledge

However, what seems to be equally important to the chosen method and the performance of using it is the leaders' ability to define and implement the knowledge reuse mechanisms. Leaders should essentially encourage knowledge to be reused and crush barriers between departments by implementing cross-functional organizational setting, both considering projects and departmental work. Likewise, it is shown that a culture of mentoring as well as encouraging rethinking and reflecting upon the daily work are critical for prosperous knowledge reuse. Thus, companies should infuse new habits, considering reuse of knowledge as a logic behavior.

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1 Introduction

In todays demanding market environment it has become decisive to have a differentiated spread of offerings available for targeted customers, work at high productivity and make fewer mistakes than competitors in order to be successful on the market, or even to stay in business (Mascitelli, 2007; Locher, 2008). The effects of differentiation, high productivity and the amount of mistakes made may be closely interrelated to how product development processes are formed to meet customer needs, how it is managed and specifically how knowledge, resulting in offerings that brings value to the customer, is exploited within the company organization (Ulrich & Eppinger, 2012).

It is claimed that, the later in the product development process errors appear, the more time and money will be required to correct these errors (Ulrich & Eppinger, 2012). An identified potential here is that the waste of not reusing knowledge, for possible success on the market, may be avoided (Locher, 2008), thus time and money can be invested differently.

1.1 Background

When company employees retire, leave their position, or go away for vacation, knowledge typically leaves with them (Harris, 2005; Locher, 2008). This phenomenon may affect organizational structures, learning capability and, as a long-term result, business financials (Locher, 2008). However, the real effects first become apparent when specific knowledge is needed, thus once knowledge is needed one may recognize that knowledge is unavailable. Generally, in product development, poor internal education, written instructions and reports of previous projects, are either too difficult to access, time-consuming to understand, can easily be wrongly interpreted, or the knowledge is in some cases not even utilized for other reasons (Locher, 2008). In product development today, one may argue that people tend to repeat mistakes, thus this may denote that organizations do not learn and knowledge reuse may, for different reasons, be neglected.

From a learning perspective, it is argued that the clearer the disseminative capacity of the knowledge source is, the richer the received knowledge will be (Tang, Mu, & MacLachlan, 2010). Thus, if knowledge is poorly proposed it can never be successfully received. Consequently, one may argue that *"the issue of transferability is important"* (Grant, 1996). Many organizations are working in projects with high demand on expertise, while, yet, organizations have problems when developing learning. This dilemma is intriguing and it puts lots of pressure on future efforts. If knowledge reuse continues to be reluctantly managed, project errors may continue to appear and the global competitive environment will eliminate companies that find difficulties adapting, alike natural selection.

Knowledge is highly valued in organizations and brings great bearing into decision-making (Grover & Davenport, 2001). It is also argued that individual knowledge is costly to re-create, why companies may desire to codify and simplify such knowledge to share it within the organization (Kogut & Zander, 1992). In recent studies, the

importance of utilizing individuals' knowledge for the benefit of the organization and company as a whole is deliberated (Wadhwa, 2012). It is also recognized that knowledge seldom is efficiently reused or shared among employees in organizations (Tang, Mu, & MacLachlan, 2010). Yet, by knowing that knowledge, organizational learning and collaborative organization structures strongly correlate to long-term financial business results and stability (Davenport, 1996; Lam, 2000; Prusak, 2001; Argyris, 2002; Wadhwa, 2012), the sharing of knowledge among employees, or the way how to reuse knowledge, becomes of great significance for future supportive solutions. Due to all the above, it is of great interest and future benefit in finding "best practices" on how to reuse knowledge in product development.

1.2 Purpose and Aim

The purpose of this Master's Thesis is to contribute with findings towards industry and the academic community by examining the complexity of knowledge reuse as a manageable resource in organizations. It is intriguing to see why many large enterprises get stuck in traditional routines of neglecting knowledge reuse, and how this phenomenon may be encountered. By observing and interviewing members from industry, the core processes of present-day knowledge reuse within product development will be identified and critically analyzed. The findings may contradict or verify literature, which is intriguing in the sense of uncovering "best practices" for knowledge reuse in product development. However, to the extent of this study, the aim is to explore the field of knowledge reuse in product development by combining theory, empirical findings and inspiration from new technology.

1.3 Research Questions

The scope of this study is grounded on two key research questions. This is basically done in order to focus, as well as limit, the research and provide a basis for evaluation of literature and empirical findings throughout the study.

Q1: What are the critical mechanisms for prosperous knowledge reuse in product development?

While reviewing theory, concerning product development and knowledge management, a list of critical mechanisms that affect knowledge reuse are presented and discussed. The factors may, to some degree, be represented by the concept of waste.

Q2: Which methods are most suitable for knowledge reuse?

Specifically, methods from the Lean product development paradigm will be investigated and evaluated. It may also be possible to outline potential issues and preconditions concerning present knowledge reuse patterns.

1.4 Delimitations

Since there is no "right" way of instructing or learning, there is neither anything such as "best practices" for knowledge to be transferred. Therefore, this study is an attempt in finding "suitable practices", formatted and applicable in a contextualized manner. This study does not consider the creation of new knowledge, thus focus is solely put on the process of knowledge reuse. The study is somewhat delimited to the concept of Lean, large enterprises and product development efforts.

Why Lean?
The Lean perspective is interesting in the sense that it is sometimes put in relation to a traditional view of product development. This "traditional vs. Lean" approach may therefore denote the extremities of how to apply knowledge management in product development.

Why Large Enterprises?
It is of great interest to examine enterprises of large scale, since these typically stresses evident concerns for huge amount of knowledge available in the organization. Therefore, knowledge management efforts correspondingly may involve greater benefits than in a smaller company, if well managed.

Why Knowledge Management in Product Development?
Product development typically involves different organizational instances, such as planning, research and development, manufacturing as well as marketing. Also, it is common to work in projects, both sequentially and in parallel. This setting is intriguing, since knowledge may be lost between departments and projects.

2 Methodology

This section describes the literature study, how data was collected and analyzed in order to answer the research questions, and how the methodology may affect the credibility of this study. The research is exploratory in its kind and the research deals with the relationships of knowledge sharing and transfer by theoretical and practical means. The study is specifically theoretic in its approach, however a case study is conducted in order to substantiate the theory.

2.1 Literature Review Assessment

The literature pre-study was grounded on books and articles. The initial phase included a wide literature study in order to broaden the theoretical base. The diverse literature mostly included fields such as epistemology, knowledge management, learning processes and Lean product development. These diverse fields of study were chosen in order to gain a broad overview of central human behavioral processes of learning and, essentially, knowledge reuse. The processes were considered from a company business approach, an organizational culture approach, and a human social interaction approach. When considering these different approaches, the main correlations within each approach are exhibited below:

- **Company business approach**
  Related to concepts of financial success, stability, strategy

- **Organizational culture approach**
  Related to concepts of organizational learning, collaborative incentives, structures, management

- **Human social interaction approach**
  Related to concepts of individual learning, motivations for individual return for reusing knowledge

By digging into the literature, especially in terms of knowledge reuse and knowledge transfer, intriguing correlations between the different fields was identified. The correlations was consequently evaluated and put into a collection of central and necessary activities related to knowledge reuse. In the sense of explicit and implicit (tacit) knowledge, it is intriguing to examine if and how knowledge can be efficiently codified and transferred. The literature review was based on digital and non-digital Chalmers library. In order to make sure that the literature was up-to-date and regarded as significant, references from fundamental works were mainly used.

2.2 Empirical Assessment

Due to the evident huge amount of knowledge created in large product development driven enterprises, the actual execution of the empirical study was performed at a major technology driven company in Sweden. Also, since product development driven enterprises typically involve different organizational instances, such as,

planning, research and development, manufacturing as well as marketing, it was intriguing to examine whether such a company may have well developed structures for knowledge reuse between departments and projects. It was also interesting to see if and how this process is systematized.

The empirical data covered both observations of daily work activity in departments of interest, and interviews with influential employees. From these observations and interviews, related and relevant information were applied and analyzed. Central in studying and observing current knowledge reuse was how the knowledge generally is communicated, if there are any routines and processes for codifying, storing and accessing knowledge in the daily work and if there are well defined structures for knowledge reuse between departments and projects.

2.2.1 Interview Sample

The empirical study was conducted at a major business enterprise in Sweden, highly sensitive to technology trends and customer needs and whishes. The data was collected while conducting interviews with ten managers. The managers have a mean work experience of 28 years within the company and work in different organizational departments, such as Research and Development, Marketing, Pricing, Product Planning, Operational Efficiency, Laws and Regulation, After Sales and Information Technologies.

2.2.2 Research Strategy

The research included challenging theory, as well as putting it into a new context of use. Since qualitative research is a suitable way to test theories, not just generating them (Bryman & Bell, 2011), the research was chosen to be predominantly qualitative in its kind. This approach was also considered to enable a deeper understanding of the knowledge reuse paradigm of large enterprises, and the qualitative approach may either verify what is stated in literature, or possibly, even hopefully, contradict what is stated in literature. This is intriguing since knowledge management is a subject of increasing interest among practitioners and companies. Why it is specifically interesting to find out if the company has well defined knowledge reuse structures is arguably to reveal practices for explaining knowledge reuse mechanisms. This could be of great use for future research and may also bring a deeper understanding for what is already suitable, and what could be more thoroughly elaborated.

2.2.3 Data Collection

Essentially, the data was collected from a perspective of guided conversations, thus semi-structured interviews. This was thought to give the interviewee enough room to touch upon interesting areas and provide intuitive knowledge, without extorting answers. Also, in some cases, even unstructured interviews were applied, which offered the interviewee total freedom to deliberate upon own experiences.

In order to provide the interviews with initial structure, an interview guide was formed. The guide consisted of a series of questions, mainly focused on how and for what reasons information and knowledge is transferred between departments and in product development projects. After the interviews were held, each interviewee had the opportunity to validate and deliberate upon their individual collected data. This was made in order to validate and generate a fair representation of what was stated during the interview.

2.3 Research Quality Apprehensions

The structure of this thesis is of scientific reference. It is aimed to fit an audience with basic insight in product development methodology, the concept of Lean and organizational structures. This, however, still puts pressure on the compliance and consistency of the report, which is intended to display an objective representation of the literature and the interviews. The chosen qualitative method for acquiring empirical data is in this context a predicament. On the one hand, it is a fundamental and rich approach to acquire important findings, however, on the other hand, the richness may be overtaken by the narrow sample. A follow-up research may therefore also include quantitative approaches, of larger samples, in order to uncover opinions that may differ from those of a small sample. A positive aspect, to the solely qualitative approach, the spread of the managers and their diverse and long experience from different departments, is, however, that the credibility of the key requirements is high and the results may be considered trustworthy. In this process it has been important to deliberate the findings in collaboration with the interviewees, in order to verify all the statements, whereas each raw material from the interviews was sent to the corresponding interviewee for verification.

3 Literature Review

In order to understand the concept of knowledge reuse, one may need to understand the notion of knowledge, thus epistemology (theory of knowledge) and knowledge management are reviewed. One may also need to recognize knowledge patterns between knowledge recipient and knowledge holder, thus learning processes in such patterns are of significance for examination. Additionally, due to the limitations of this study, the Lean concept of product development, and especially knowledge reuse, is of great importance, thus likewise reviewed.

3.1 Data, Information, Knowledge and Wisdom

It can be said that there is a distinction between data, information, knowledge and wisdom. Below the definition of each are illustrated and formulated.

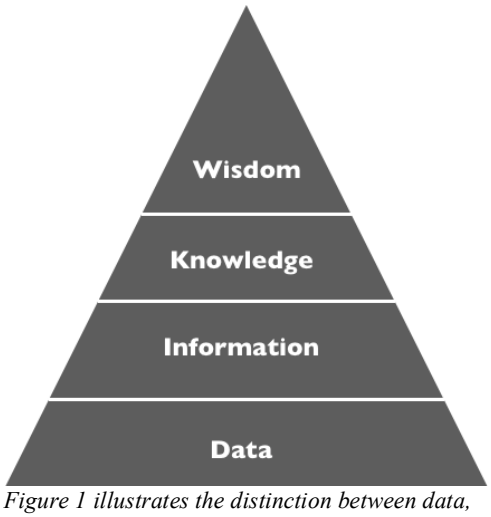


Figure 1 illustrates the distinction between data, information, knowledge and wisdom.

Oxford dictionaries (2013) define each as:

- **Data**
  "Facts and statistics collected together for reference or analysis"

- **Information**
  "Facts provided or learned about something or someone"

- **Knowledge**
  "Facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject"

- **Wisdom**
  "The quality of having experience, knowledge, and good judgment; the quality of being wise"

3.2 Epistemology – Theory of Knowledge

The study of knowledge has puzzled philosophers since ancient times, and documentation considering knowledge as knowing and reasons for knowing can be found from both west and east. Knowledge has for ages been the basis for guiding in the spiritual and secular life. A lot of these early efforts were focused on acquiring theoretical and cognitive understandings of what knowledge is all about (Wiig, 1999). Since then, the view on knowledge has been rationalized, and according to Oxford Dictionaries knowledge is defined as *"facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject"* (Oxford Dictionaries, 2013). Accordingly, there is a discrepancy between different kinds of knowledge. In the literature one can recognize an epistemological distinction between "knowing about" and "knowing how". The identified difference between these two definitions can be found in the transferability, thus how the transfer between knowledge holder and knowledge recipient is expressed (Grant, 1996). Depending on the literature, the two types of knowledge are termed differently. Either it is objective vs. subjective, prepositional vs. personal (Grant, 1996), declarative vs. procedural (Kogut & Zander, 1992), or explicit vs. tacit (implicit) knowledge (Polanyi, 1967; Nonaka, 2007). In this study, the types termed explicit and tacit knowledge are reviewed.

3.2.1 Explicit Knowledge

Explicit knowledge is information-based, formal and methodical and can be communicated and shared in books, reports, requirements specifications, scientific methods or computer programs (Nonaka, 2007; Lejeune, 2011). This formalized knowledge can easily be transferred through reading, demonstration, analysis (Lam, 2000), or through information technology (Stenmark, 2005).

3.2.2 Tacit Knowledge

Tacit knowledge is the knowledge that has not been articulated (Platts & Yeung, 2000). It is informal and said to be difficult to communicate. Yet, if tacit knowledge cannot be codified, the transfer is slow, costly, and uncertain (Kogut & Zander, 1992). Tacit knowledge can be represented by subjective insights, intuitions, and hunches (Nonaka, 2007). However, it can also be argued that there are two different kinds of tacit knowledge (Platts & Yeung, 2000). One that is based on experience, rooted in the individual behavior or in the work community, and one based on intelligence, deeply rooted in our minds. The experience-based tacit knowledge may be built up by actions by means of complexity, speed, and simultaneity, which typically are difficult to describe in writing (Kogut & Zander, 1992). Yet, it is argued that experience-based tacit knowledge may be made explicit through identification and reflection (Platts & Yeung, 2000). The intelligence-based tacit knowledge may involve recognizing patterns and abilities of understanding subtle relationships. It can be contextualized as great insights (Nonaka, 2007) when solving complex problems that involve high speed and simultaneous tasks that rarely can be slowed down or trained gradually (Platts & Yeung, 2000). In product development projects, both the experience-based and intelligence-based tacit knowledge is essential. However, it is merely the experience-based tacit knowledge that, with substantial effect, can be transferred by practical means (NTL Institute for Applied Behavioral Science, 2013), unlike the intelligence-based. The sharing and transfer of the experience-based tacit knowledge is therefore of outmost significance for management efforts in product development.

3.2.3 Six Characteristics of Knowledge

According to Kluge, Stein and Licht (2001) there are six characteristics that differentiate knowledge from other assets:

1. ***Transferability*** – knowledge can be successfully extracted from one context to another
2. ***Subjectivity*** – knowledge can be interpreted differently, which may be dependent on people's knowledge base and the applied context
3. *Embeddedness* – knowledge can be difficult to access or reformulate
4. *Self-reinforcement* – knowledge does not lose value when it is shared, in fact the value of it may grow when it is widely spread
5. *Perishability* – knowledge may become obsolete over time
6. *Spontaneity* – knowledge can develop impulsively in a process that is difficult to control

Since knowledge will transfer from a source to a recipient, with the ability to interpret differently from the source, subjectivity and transferability are considered of outmost concern for prosperous knowledge reuse.

3.2.4 Transferability of Knowledge

In terms of transferability between explicit and tacit knowledge, the following extractions can be considered:

- ***Explicit to Explicit***
  Explicit to explicit knowledge transfer can be represented by information that is written and shared in reports, where new knowledge is synthesized into information from many different sources (Nonaka, 2007)

- ***Tacit to Tacit***
  Tacit to tacit knowledge transfer can, by efficient means, be made through observing skills, imitate and practice (NTL Institute for Applied Behavioral Science, 2013). However, the methodical understanding in this kind of knowledge transfer is often lost (Nonaka, 2007)

- ***Explicit to Tacit***
  Explicit to tacit knowledge transfer represents the creation and reframing of information into own tacit knowledge. In the long run, new individual innovations become resources, necessary in the daily work (Nonaka, 2007)

- ***Tacit to Explicit***
  When tacit knowledge is expressed in its core, it can be converted into explicit knowledge. However, the conversion of tacit knowledge into explicit knowledge implies the expressing a model of the inexpressible (Nonaka, 2007)

3.2.5 Subjectivity of Knowledge

Typically, efforts to move in a common direction can be foiled by misunderstandings. Available solutions or knowledge may lie unutilized because employees simply do not realize or understand the benefit of it, or it may be ignored if they do not see how it can be applied (Kluge, Stein, & Licht, 2001). Thus, what may seem to be clear to

one person may be seen as unclear to another. This may be true since knowledge is subjective (Kluge, Stein, & Licht, 2001). The word "subjective" may be defined as *"based on or influenced by personal feelings, tastes, or opinions"* (Oxford Dictionaries, 2013). There are different characteristics that may affect the subjectivity, such as expertise, education and status. Subjectivity is claimed to be *"a component of every knowledge management problem"* (Kluge, Stein, & Licht, 2001).

3.2.6 Knowledge Management in Organizations

The first uprising of knowledge management within organizations, by modern means, was recognized after the World War II. At this time, it also gained scientific recognition (Kiehl, 2004). Knowledge management developed as a fundamental response to the radical social and economic changes during that time, such as globalization and the uprising knowledge-centric view of the company. At this time, trade and global players increased significantly and continuous efforts were made in the development of computing technologies (Prusak, 2001). When, especially, outlining the evolution of computing technologies in companies, its impact seems to be decisive for information management history and development. During the 1960s electronic data processing infringed companies, and the management information systems developed during the 1970s included a small amount of managerial control, such as personnel, money and physical goods. During the 1980s, information grew larger inside firms and the information systems groups within organizations tried to understand what kind of information managers really needed to make decisions. At this time, the PC had a huge impact on organizational structures (Grover & Davenport, 2001). The understanding and importance of organizational knowledge has evidently changed during the years, and in the 1990s knowledge started to be considered as a strategy and a manageable resource in business practice and theory (Kiehl, 2004).

> *"The best future for knowledge management would be for it to become so pervasive and common that it seems invisible"* (Grover & Davenport, 2001)

3.2.7 Organizational Knowledge Structures

In its root, the organization is a cognitive enterprise where knowledge is developed and learned (Nonaka, 2007; Lam, 2000). In this context, knowledge structures refer to the shared attitudes at organizational level, comparably defined by Argyris & Schön (1978) as relationships, behaviors and actions made by members of the organization (Argyris & Schön, 1978). The organizational structures also carry bureaucracy and evident transfer barriers, such as common ambiguity and inefficient means of communication (Tang, Mu, & MacLachlan, 2010). However, it is not necessarily the sharing of knowledge that influences organizational behavior or problem solving, but instead the organizational mutual understandings (Lylses & Schwenk, 1992).

> *"Tacit knowledge must be actively recognized and afforded the same amount of management attention as explicit knowledge receives"* (Platts & Yeung, 2000)

The western traditional management approach of knowledge has usually been concentrated upon so called explicit knowledge – defined as information that easily can be spread through writing. However, tacit knowledge – knowledge as skill or "know-how" – is regularly, but indeed involuntary, neglected (Platts & Yeung, 2000). In this sense, the common disregard for the knowledge transfer activities can be seen as a severe limitation in business (Grant, 1996). This limitation can be claimed to

restrain creativity, and, in product development, creativity is a core activity for innovation.

Most practitioners consider commitment, company identification and understanding as core factors for a healthy organizational culture (Nonaka, 2007; Davenport, 1996; Wadhwa, 2012). And commonly it is said that getting people to learn is based on individual motivation, meaning that individuals learn automatically when committed (Wadhwa, 2012). However, this might mislead companies to focus all attention merely on organizational structures – the creation of performance reviews and corporate cultures. Learning is arguably not solely involving individual attitudes, but also personal growth, in terms of rethinking and reflecting (Argyris, 2002). Rethinking may be defined as *"consider or assess (something, especially a course of action) again, especially in order to change it"* and reflecting may be defined as *"think deeply or carefully about"* something (Oxford Dictionaries, 2013).

3.3 Learning Processes

Learning processes may arguably be the core feature of successful knowledge reuse, since if knowledge is inefficiently proposed and understood it may be considered useless. Prusak (2001) writes that *"if organizations can manage the learning process better, then they can become more efficient"*. This statement can be seen as very simplistic and primitive, but it is also appropriately straightforward. Still, one might ask oneself what an appropriate learning process is? Arguably it is the knowledge holders' ability to structure knowledge and express it convincingly that affects how recipients will make new knowledge of it (Tang, Mu, & MacLachlan, 2010). Accordingly, the recipients' involvement is core to a successful learning. Recipients need to reflect critically on their own behavior to truly gain new knowledge (Argyris, 2002).

Managers "misunderstand what learning is and how to bring it about" (Argyris, 2002)

During the years, general models describing learning methods have been established. The most famous one is probably the *"Learning Pyramid"* developed by the Institute for Applied Behavioral Science. The concluding extracts from this scientific model, based on learning theory, suggests that people learn best when they are actively involved in the learning process (NTL Institute for Applied Behavioral Science, 2013).

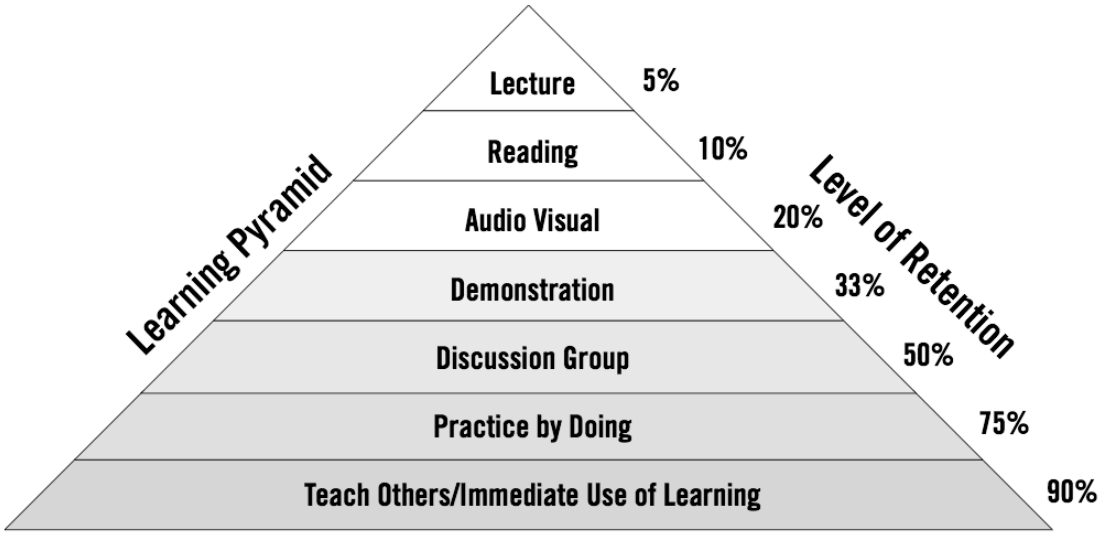


Figure 2 illustrate the Learning Pyramid, where the estimated learning retention rates are dependent on the learning approach (NTL Institute for Applied Behavioral Science, 2013).

The upper part of the Learning Pyramid represents methods primarily related to transfer of trivial and shallow, so-called explicit, knowledge, while the lower part is primarily related to transfer of deeply rooted, so-called tacit, knowledge, while the bottom of the Learning Pyramid is related to the transfer of tacit knowledge, in the sense of skill and "know-how".

"The learning and innovative capability of an organization is… …critically dependent on its capacity to mobilize tacit knowledge and foster its interactions with explicit knowledge" (Lam, 2000)

3.3.1 "Tacit-Explicit-Tacit" Model

Attempts of creating general guidelines, transferring knowledge explicitly, which in turn are based on well-known theories, have shown that intuitive or "gut-feel" decision-making are lost in the process (Platts & Yeung, 2000). Yet, Nonaka (2007) proposed a model of turning tacit knowledge into explicit knowledge, and then over to tacit knowledge again. It can be represented by the slightly modified version below:

1. **Socialize**
   Learn the tacit secrets
2. **Articulate**
   Translate the tacit secrets into explicit knowledge, represented by e.g. a method
3. **Combine**
   Standardize and formulate a manual representing it in a product
4. **Internalize**
   From experience, enrich individual tacit knowledge base of understanding intuition

Note that **point number 2** is core for the *tacit to explicit* knowledge transfer, and **point number 4** is core for the *explicit to tacit* knowledge transfer, since it includes personal commitment and change.

Through this model, the knowledge base, represented by the organization as a whole, grows (Nonaka, 2007). Though, the greatest challenge here is probably to manage the process between *tacit to explicit* knowledge, since there are several issues related to this activity. Decisions made by individuals may be performed without truly knowing the genuine process, making some decisions invisible to the rest of the organization (Platts & Yeung, 2000). Polanyi (1967) once stated, *"we can know more than we can tell"*, and this might cause confusion. In business, where results are prior, managers repeatedly, however unintentionally, neglect activities of codifying knowledge (Mascitelli, 2007). Due to the transactional nature of explicit knowledge transfer, and its limiting involvement of interaction, it can be argued that this transfer is likely to hinder creativity, where interaction is claimed to, at its root, form creativity (Platts & Yeung, 2000).

3.3.2 Experiential Learning Model of NTL and PDCA Process

The Experiential Learning Model is based on research from behavioral science. It is focused on helping the individual to fully be engaged in their learning (NTL Institute for Applied Behavioral Science, 2013). The model is very alike the LAMDA process, described in section 3.4.4.1, and the PDCA process (Deming-cycle) described in short below.

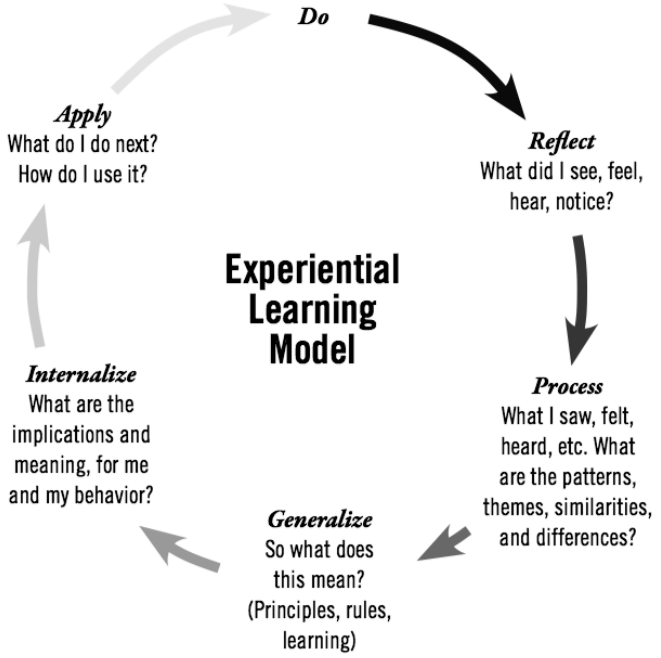


Figure 3 illustrate the Experiential Learning Model (NTL Institute for Applied Behavioral Science, 2013).

The PDCA process stands for Plan-Do-Check-Act, which means:

- Plan – Understand the problem
- Do – Go through with the plan
- Check – Evaluate and analyze what was successful or not, and why
- Act – Implement, or make improvements by repeating the cycle

3.4 Knowledge Approach of Lean Product Development

In Lean Product Development, there is a general desire to reduce complexity and the number of interrelations (Locher, 2008). Below a table of the thirteen principles of Toyota Product Development System is presented in order to overview the typical Lean approach.

Process 1. Establish customer-defined value to separate value add from waste 2. Front-load the product development process to thoroughly explore alternative solutions while there is maximum design "space" 3. Create a leveled product development process flow 4. Utilize rigorous standardization to reduce variation, and create flexibility and predictable outcomes
Skilled People 5. Develop a Chief Engineer system to integrate development from start to finish 6. Organize to balance functional expertise and cross-functional integration 7. Develop towering technical competence in all engineers 8. Fully integrate suppliers into the product development system 9. Build in learning and continuous improvement 10. Build a culture to support excellence and relentless improvement
Tools and Technology 11. Adapt technology to fit your people and process 12. Align your organization through simple, visual communication 13. Use powerful tools for standardization and organizational learning

Table 1. The Thirteen Principles of the Toyota Product Development System (Locher, 2008).

This way of approaching product development is highly focused on setting up elaborated structures, maintaining holistic perspectives throughout the development, customer focus, respect for individuals, and knowledge is seen as the highest valuable resource, and especially the reuse of it. However, in order to generalize the Lean concept from a traditional approach further, the two concepts may be differentiated as follow:

> **Traditional:** *"Did we get a prototype to pass by the designated milestone date?"* (Locher, 2008)
>
> **Lean:** *"What did we learn from our studies that can be shared with others in the organization, and could we have learned any more effectively or efficiently?"* (Locher, 2008)

This differentiation between a traditional approach and a Lean approach signal the prominence of changing basic behavioral structures and general thinking. By identifying waste in processes and finding ways in how to eliminate that waste, one may find a rich value stream, connecting added value directly towards the customer.

3.4.1 Waste in Product Development

Waste is, by means of the Lean concept, defined as, *"any thing or process that does not add value to the customer or user"*.

Mascitelli (2007) defines a list of common sources of Product Development waste:

- Chaotic work environment – constant interruptions
- Lack of available resources – resource bottlenecks
- Lack of clear prioritizations of projects/tasks
- Poor communication across functional barriers
- Poorly defined product requirements
- Disruptive changes to product requirements
- Lack of early consideration of manufacturability
- Overdesigning, analysis paralysis, gold-plating
- Too many @!%&* meetings
- E-mail overload - the ”e-mail avalanche”

Accordingly, Locher (2008) defines sources of Product Development waste as:

Overproduction	• Completing design elements that are not needed for some time • Including features that the customer does not see as a value (could also be included in nonvalue-added or overprocessing waste) • "Over-engineering"
Waiting	• Approvals from superiors • A lack of available capacity • Input from customers • System response time • Completion of other design elements
Transportation	• E-mailing information • Multiple hand-offs • Report distribution • Circulating paperwork for signatures
Nonvalue-Added Processing (or Overprocessing)	• Reentering data • Extra copies • Unnecessary or excessive reports or paperwork • Redesigning something that already has been designed (i.e., reinventing the wheel) • Most engineering support services
Excess Inventory	• Filled in-boxes (electronic or paper) • Batch processing transactions • "Large" design releases • Retaining documents beyond what is required
Defects (or Correction)	• Design errors • Service failures • Engineering change orders due to errors • Not clearly understanding customer needs • Missing or incomplete information
Excess Motion	• Going to/from printer, fax machine, central filing, and meetings • Travel

Underutilized People	• Limited authority and responsibility for basic tasks • Management "command and control" • Not sufficiently sharing knowledge • Not involving suppliers early in the development process • Not involving manufacturing early in the development process

Table 2. Waste in Product Development (Locher, 2008)

3.4.2 Knowledge Value Stream

A company typically has a vision, and the objectives towards that vision may be driven by knowledge. Lets say that, if knowledge acquired from project "one" is reused in forthcoming project "two", the initial available knowledge in project "two" is greater than in project "one" (Kennedy, 2008; Holmdahl, 2010). This knowledge value stream is illustrated in *Figure 4*.

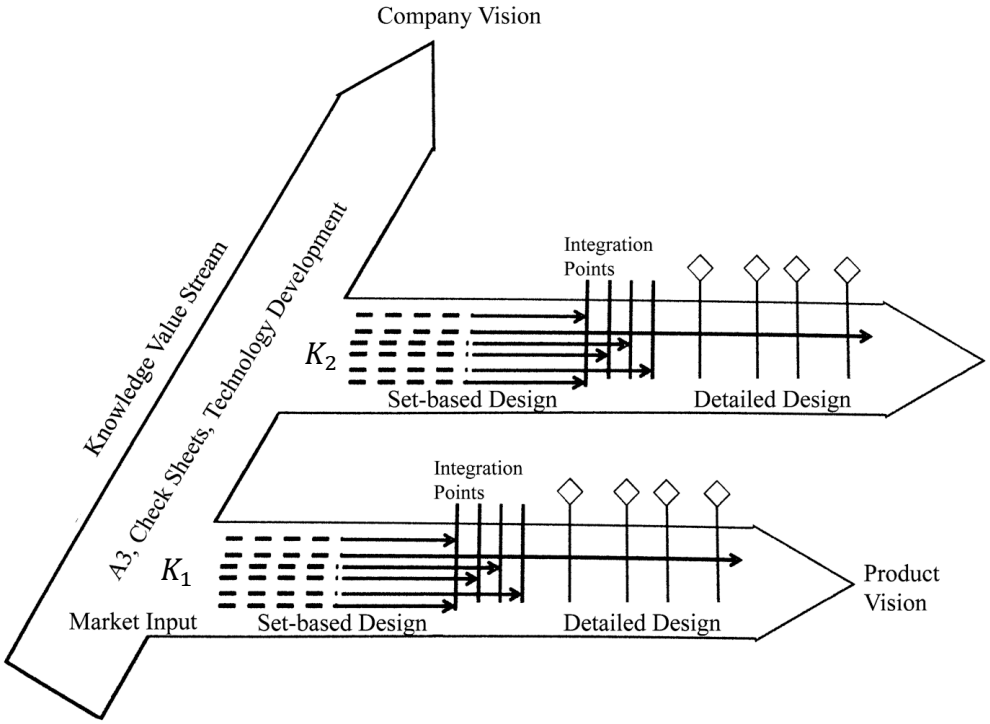


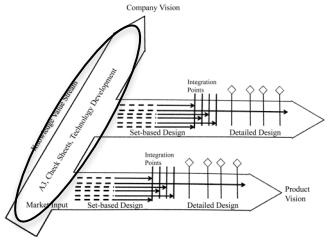
Figure 4 illustrate the knowledge value stream in Lean Product Development (Holmdahl, 2010). Due to the reuse of knowledge between projects, $K_2 > K_1$.

In accordance to the knowledge value stream, most organizations ought to recognize that many design activities engage knowledge reuse rather than knowledge creation. In this very sense, organizations must develop highly effective and efficient practices for reusing knowledge, as well as sharing it to the people involved in the design process (Locher, 2008).

3.4.3 The "Lessons Learned" Dilemma

"Lessons learned" may be incorporated into the design process to improve performance in future projects. It involves identifying and classifying the actual value of time-consuming and costly iterations. In many organizations, "lessons learned" activities are often known for its general benefits. However, the codifying process of learned experiences are often left incomplete, as the employees who codify are rapidly assigned to another project. Regularly, the codifying activity of lessons-

learned becomes a dull duty, whilst the idea of supportive use in future projects is forgotten, thus wasting the purpose of it (Locher, 2008).



3.4.4 Knowledge Reuse Methods

Knowledge reuse is based on iteration processes, which include update and validity of present knowledge (Locher, 2008). It may also include standardized arrangements, in order for future development teams to grasp the codified knowledge quickly. In accordance to this, it is stated that if people experience even an ounce of resistance when searching for information or knowledge, they may give up and choose to reinvent the wheel (Mascitelli, 2007). When knowledge is codified, organizations are required to engage time to do it properly. It is likewise important to make it easily retrievable (Locher, 2008).

"Good iterations are when an organization learns" (Locher, 2008)

It is said that, the more validated knowledge that is reused, the lower is the chance for bad iterations (Locher, 2008).

3.4.4.1 Method: LAMDA

LAMDA method describes a way of working. It may be conceived as a process to address problems and to solve them (Holmdahl, 2010).

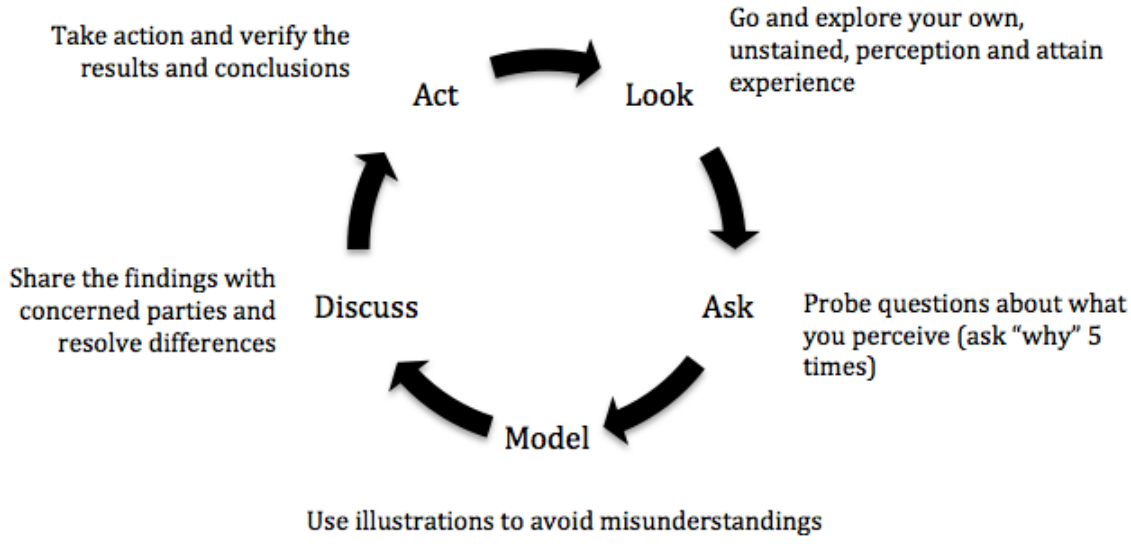


Figure 5 illustrate the LAMDA-process.

3.4.4.2 Method: A3

A3 reports are based on the LAMDA-process, and are typically prepared for problem solving, proposals, status report or competitive analysis. Due to the format of A3, it is well suited as a structure for overviewing reports. A traditional A4 is usually too small to fit figures, diagrams and explaining texts (Holmdahl, 2010).

3.4.4.3 Method: Check-Sheets

Usually, manufacturing manuals are focused upon technical solutions. Check-sheets are typically aimed to describe, with illustrations and short describing text, the limits for what can be manufactured, driven by quality and cost. It is less about technical solutions and more of manufacturing aspects and tolerances, thus the company's capability. Traditionally, engineers typically need to remember specific and important details, or ask experienced engineers to guide them in the search (Holmdahl, 2010). In this way, engineers may find a basis for streamlining the design process. However, this may be a time-consuming and costly process that relies on people's memories and their availability (Locher, 2008). Due to this, a standardized check-sheet with questions and answers may be applied, as described in *Figure 7*.

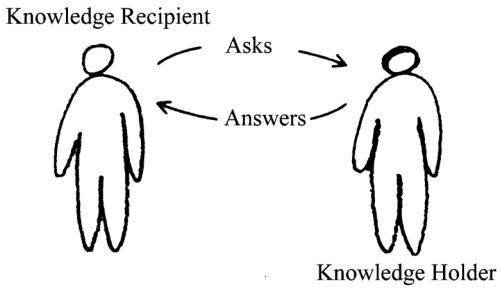


Figure 6 illustrate a traditional approach of communication in product development (Holmdahl, 2010).

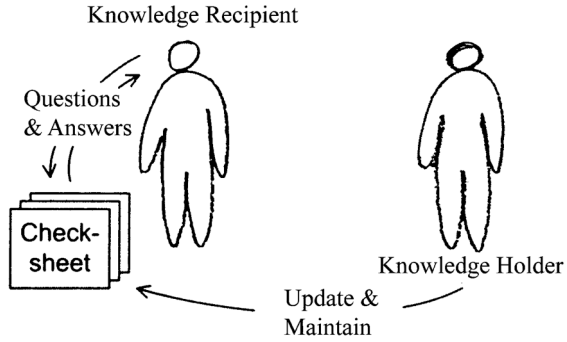


Figure 7 illustrate use of check-sheet for communication support in product development (Holmdahl, 2010).

In order to highlight any known risks and common errors, there may also be a need to consider check-sheets as "living" (Mascitelli, 2007). To prevent rework in future projects, check-sheets must be carefully updated and maintained (Locher, 2008). One way of managing check-sheets would be to assign one person responsible of a check-sheet (Mascitelli, 2007), typically an employee who possesses great knowledge in manufacturing.

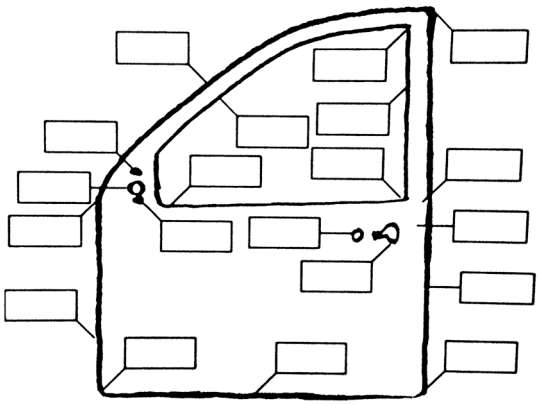
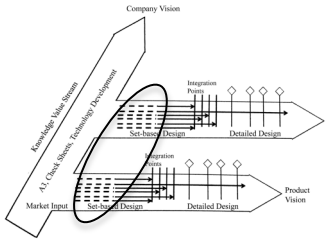


Figure 8 illustrate an example on how you may prepare a check-sheet for support in knowledge reuse in a visual context with short descriptions (Holmdahl, 2010).



3.4.5 Set-Based Design

In different phases of a product development process, varying amounts of time may be spent to efficiently influence the project outcome. As one can recognize in Figure 9, knowledge acquiring is, in the Lean approach, described as essential in early phases, whilst the traditional approach puts more efforts in later phases. Product changes in late phases due to early mistakes typically involve high cost and possibly delay of product launch.

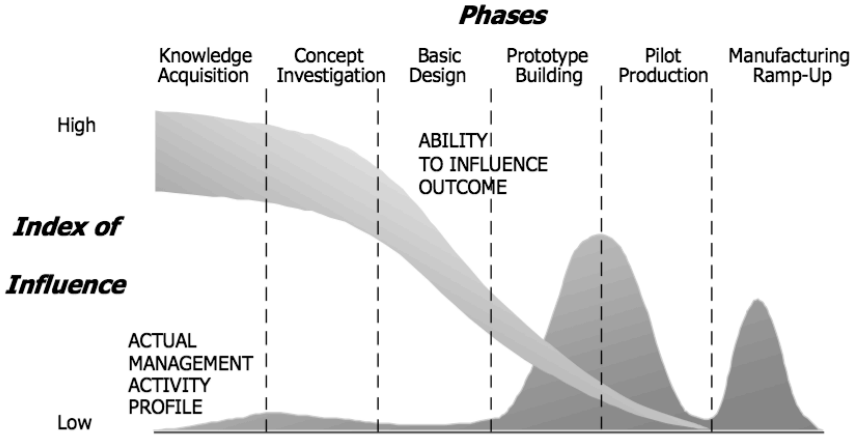


Figure 9. Illustrates how the traditional management activities differ from ideal activities and demonstrates the importance of acquiring knowledge in early phases of product development (Trygg, 2011).

The driving forces for set-based design may be (Holmdahl, 2010):

- Decisions are taken early and without enough knowledge and information
  - Decisions on concepts and architecture, which are the most important decisions, are chosen when the knowledge and information base are at its weakest point. The projects are then aimed at optimizing and iterate until specification are met.
- There is a risk of not choosing the best concept
  - Traditionally in product development there are certain phases and gates to follow, where the concept should be chosen in early phases. There is a belief that early decisions on concepts and interfaces between subsystems allow independent, parallel work. The investigation of different concepts may therefore be hindered by the early decision on chosen concept.
- Coupled activities involve intensive communicating
  - Subsystems may be dependent of each other, meaning that the dimensioning of a marine engine is dependent on the weight of the boat, given a desired speed.
- Intensive communicating involve low efficiency
  - A change of a subsystem solution may affect the functionality of another subsystem solution. This implies intensive communicating, while time spent on developing is low.

3.4.6 Managing Knowledge Reuse

Project deliverables are often classified as company results, which may be measured through statistics of customer or user satisfaction. This result-based focus may put the important insight of considering the future need for knowledge too late in the development process. Thus codifying activities are seldom cared the amount of time needed to efficiently be able to reuse knowledge in the future (Locher, 2008). Also, there is typically a lack of standardized methods of knowledge reuse in product development (Mascitelli, 2007), which may generate a scattered organization in terms of how to codify. By structuring a healthy organizational culture towards the future need for knowledge, one may construct a habit that foster organizational learning.

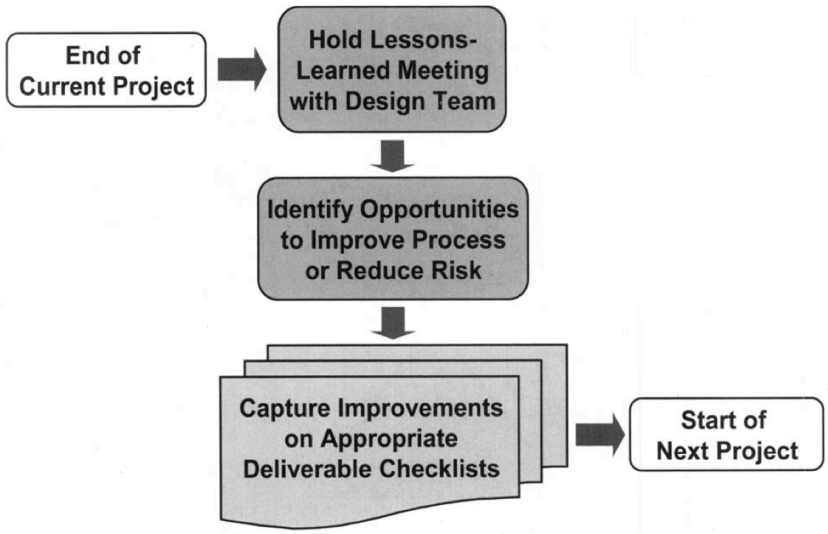


Figure 10 illustrate the process of managing knowledge in the end of a project. Through these management efforts, valuable experiences may be harnessed and in best-case scenario it will even foster organizational learning and knowledge reuse (Mascitelli, 2007).

When fostering knowledge reuse habits, engineers and designers ought to be encouraged to make use of existing parts and components without any redesign, unless there is a specific value adding need for a redesign (Locher, 2008).

"Product variations often do little to better meet customer needs or lower the cost of meeting those needs. Most often they simply result in increasing the cost of development" (Locher, 2008)

3.5 Supplementary Conditions for Efficient Knowledge Reuse

In this section, various supplementary conditions for efficient knowledge reuse, such as social interaction and organizational settings, are reviewed from the perspective of what may describe or contribute to an environment that foster efficient knowledge reuse. Thus, there are other identified aspects to consider besides knowledge reuse methods in order for knowledge reuse to be as efficient as possible. What is believed to indeed be intriguing is to deliberate social interaction in terms of mentoring, cross-functional setting and new technology for interactive knowledge reuse.

3.5.1 Mentoring

In organizations managers may achieve tacit knowledge transfer through training in mutually supportive team environments (Harris, 2005). In such a collaborative setting, new ideas are allowed to bounce between individuals, creating understanding, trust, and building on existing knowledge (Wadhwa, 2012). Mentoring is however very resource demanding and requires a highly supportive environment (Platts & Yeung, 2000).

3.5.2 Traditional vs. Cross-Functional Organizational Setting

Traditionally in large enterprises, it is common to divide work between functional organizational silos. This may create a throw-over-the-wall setting, meaning that documents and knowledge pass from one department to another with low degree of interdepartmental communication. Functional organizations may find difficulties in coordinating project decisions from all functional areas (Ulrich & Eppinger, 2012). This setting in combination with dissimilar codifying routines between departments may call for greater integration issues between departments, loss of holistic perspectives and high degree of organizational indifference. In the long run, along complex technology advances, problems and inflexibility may develop. The mentality of *"I do my job, you do yours"* may have the effect of misunderstandings. This makes it impossible for individual departments to realize their holistic contribution (Doyle, 1991).

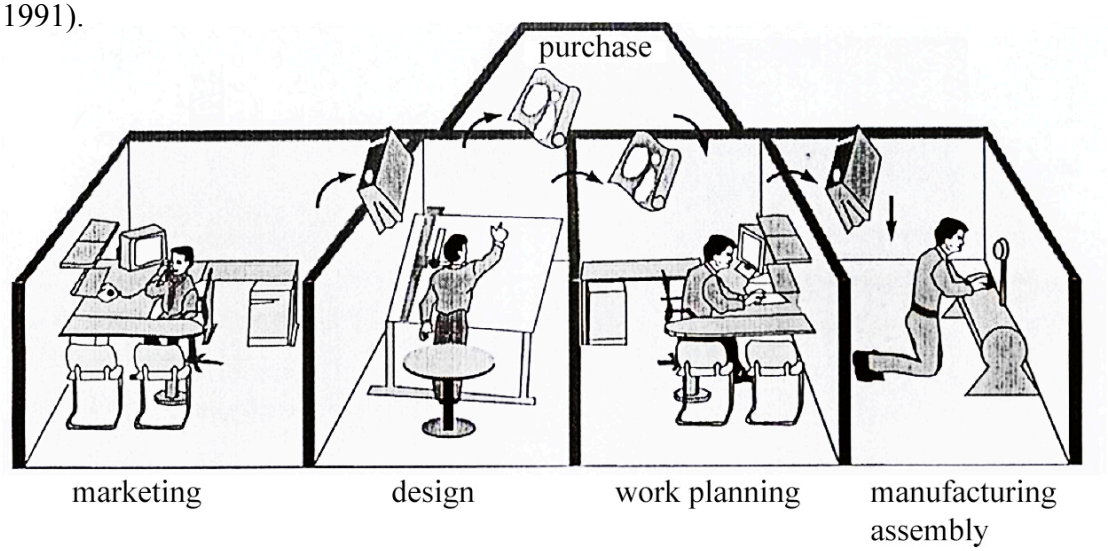


Figure 11 illustrate the traditional functional organizational structure (Trygg, 2011).

3.5.2.1 Integration Barriers

"Integration is the process of achieving unity among the various subsystems in the accomplishment of the organizations' task" (Lawrence & Lorsc, 1967). Thus, it may be suggested that standardizing interfaces in modular system architectures of many types may be a new dominant design for achieving increased flexibility and internal organizational connectivity among broadly de-integrating organizations.

Integration barriers between departments may include (Trygg, 2011):

- Competence
- Status
- Culture
- Organizational affiliation

- Geographical distance
- Goals
- Time pressure
- Information availability

3.5.2.2 Cross-Functional Setting

In development projects of complex products, cross-functional setting will foster a combined knowledge base to meet high demands from the market. Cross-functional setting usually implies that a group is represented as a variety of employees from different organizational departments, disciplines, or functions that together will achieve certain group goals (Henke, Krachenberg, & Lyons, 1993). However, bringing together a diverse group of experts, with diverse skills and a unique perspective on problems, may be seen as a barrier for success and puts high demands on management. In contrast, it is excessively difficult and complex for one department to get a holistic view, identifying all the breaking points and obstacles in a project (Parker, 2003). Typically small group sizes are suggested, since increasing group size arguably leads to decreasing productivity, member involvement, participation and trust (Henke, Krachenberg, & Lyons, 1993). The optimal size depends on the specific group mission and the complexity of the task. If the functional diversity becomes too great, it may create information overload, which typically increases the general complexity of the group's problem solving (Sethi, Smith, & Park, 2001).

"The greater the task uncertainty, the greater the amount of information that must be processed among decision makers during task execution in order to achieve a given level of performance" (Galbraith, 1973)

As companies define quality as satisfying the customer it also makes sense to include customer representatives on the cross-functional quality improvement and product development teams (Parker, 2003). Supplier and customer involvement in cross-functional setting may bring advantages, in the sense of mutually agreed-upon quality standards, production processes, paperwork processes and delivery schedules (Henke, Krachenberg, & Lyons, 1993). Cross-functional setting is especially effective in fast-changing markets such as high tech companies (Parker, 2003). For example, when working with platform projects, a whole new generation of products with significant performance changes will affect different areas, why cross-functional setting is of great use (Wheelright & Clark, 1992).

In a cross-functional setting, members could learn from each other and bring knowledge back to their home department, with a higher skill-set and broader understanding of the company and its target market (Wang & He, 2008). In the end this may foster a reuse of knowledge and experience, passing it through all departments. As a result of the increased understanding, the internal communication in the company will improve, thus resisting relationship between former group members. A result may be that the decision-making in the company gets decentralized (Henke, Krachenberg, & Lyons, 1993), which may imply that less information bounces back and forth, which speeds up the development process. This is claimed to be one of the main advantages of implementing a cross-functional setting (Parker, 2003). There are also difficulties in managing cross-functional integration. Members with different background, expertise, culture, language and experience are, in the

sense of knowledge base, broader than members with identical background. A cross-functional setting is however far more demanding and complex to manage than a traditional functional setting. For example, managers need a wide range of technical expertise to be able to understand all the different aspects of a project (Parker, 2003).

3.5.3 New Technology for Interactive Knowledge Reuse

Information systems technology is developing extremely fast. And above all, traffic and storage of data is constantly increasing. According to Cisco, global data traffic over the Internet will have an annual growth rate of 31% from 2011 to 2016 (Cisco, 2013).

Today, knowledge can easily be accessed and shared through different interactive media and the digital social environment has been the main driving force in the information system development during the last couple of years. Can businesses utilize new information systems technology? In fact, in a lot of business organizations the use of digital tools to share information has mainly been provided as so-called intranet. Unlike the Internet, intranet information is accessible exclusively among employees (Stenmark, 2005). The use of intranet, to share information in organizations, is thus not new. In 1989, Tim Berners-Lee identified the interactions of information flow at CERN (The European Organization for Nuclear Research) as a web of growing interconnections (Berners-Lee T. , 1989). These interconnections were developed and designed to be *"a pool of human knowledge, which would allow collaborators in remote sites to share their ideas..."* (Berners-Lee T. e., 1994). Hence, the new solution opened up for sharing information and knowledge to other peers in the organization. Despite this evident potential of sharing information and knowledge, and make use of it, it seems that a lot of storage and sharing through business intranet is merely data.

The knowledge of the firm is socially embedded. It is rooted in the firm's coordination mechanisms and organizational routines (Lam, 2000)

It has, until now, been difficult to develop technologies that support an interactive based knowledge reuse culture in companies. However, today, new technology offers the possibility to learn through a digital interactive environment, placing supportive solutions in the center of development. Accordingly, social interactive technologies are widespread, and there is a huge potential for knowledge sharing through interactions in business environments (Davenport, 1996; Wadhwa, 2012). However, a lot of large businesses have not yet been able to efficiently make use of existing technologies in a way where, especially tacit knowledge can be shared. Although, communicating knowledge through new technology and products might still not be the full comprehensive solution. Knowledge management and learning cannot be left to databases and intranets alone (Platts & Yeung, 2000), meaning that a computer system is unable to share knowledge by itself.

In product development projects, it is argued that flexibility is core to management actions (Nobelius & Trygg, 2002) and that managers should be as comfortable with knowledge reuse methods, such as visualizing symbols and slogans, as they are with controlling business productivity and ROI (Nonaka, 2007). The distinguished phenomenon of somewhat careless management of knowledge reuse may be due to the fact that the codifying, storing, accessing and deploying of information and knowledge seldom is updated or maintained accordingly with the amount of new

knowledge that is added. Accordingly, it is argued that these organizational activities are fundamental for successful knowledge transfer (Grant, 1996). Though, bringing interactions, embedded in new technology into business understanding is yet a great challenge. While it is also important to notice that, collaborative learning facilitates engagement, while encouraging an environment of learning and innovation, as a culture (Wadhwa, 2012; Lam, 2000).

4 Empirical Data Collection and Analysis

In this section, all interviewees' opinions and experiences of managing knowledge reuse within, as well as between, projects and departments are examined. This is primarily done in order to verify or contradict literature and to propose valuable findings for company representatives.

4.1 Summary of Present-day Knowledge Reuse Management

It does not seem to be one consistent approach in how to make knowledge reusable within the company. The primary knowledge transfer methods in the company can be summarized into categories of social interactions, codifying knowledge, and storing as well as accessing it via computer software.

4.1.1 Social Interactions

It is said that social interactions are the core means of communication. This puts efforts in coordinating people and may imply that ”time availability” is one limiting factor. One also needs to put efforts in building up social network channels to be able to gain the knowledge. The most apparent methods for acquiring knowledge through social interactions are presented below.

1. Formal group meetings
2. Encounters between individuals consisting of straightforward face-to-face communication, mostly within each functional organizational landscape, but also between departments
3. Telephone calls

In the general daily work, a lot of meetings are held, where problems and project status are discussed. It is stated that there is a need for utilizing each other's experience and knowledge in daily work activities. And to gain this knowledge one typically tries to get a hold of a person with the wanted expertise to discuss issues ad hoc in the organizational landscape. It is in this sense claimed to be important to bounce ideas between employees and managers to share knowledge in the hierarchical structure. However, apparently there is an issue when trying to get a hold of a person with the needed expertise, since there are a lot of meetings.

4.1.2 Codifying Knowledge

The codifying work of knowledge in the company is driven by “neat and tidy” work. Without that input, the richness of knowledge is said to be poor. This means that it is expected of the individual that codify knowledge to hold a personal characteristic of being “neat and tidy”. According to the interviewees, the use of tables in reports is typical when extracting important learning. However, in meetings, graphical illustrations are regularly used, since it is claimed to be an efficient way of sharing knowledge.

The way in which knowledge is codified, for what reason, and how it is stored is summarized below.

How Knowledge is Codified

1. Lists
2. Tables
3. Brief written text
4. Illustrations
5. Written text with more precise and detailed explanations
6. *"Visualize so that anyone can understand it"*

Below, the most common reasons for knowledge to be codified are presented:

Reasons for Knowledge to be Codified

1. Extract important facts, such as requirements
2. Decisions
3. Laws and regulation
4. Product changes
5. Cost
6. For future users
7. Orderliness

Some of the interviewees consider codifying efforts as very important, *"we need to focus on the content and substance of what is documented. If you are not clear and distinct in the documentation, you will not be clear for future users"*. However, one might find it difficult to set it into action due to time constraints and scattered routines. It is stated that checklists are used to prevent this. However, the checklists may be filled without knowing why and for what good. It is also said that it is important to be able to go back in documentation and understand why decisions were taken, and to make consistent judgments, especially if someone retires.

4.1.3 Storing and Accessing Coded Knowledge via Software

It is stated that it is difficult to access knowledge via software. Therefore, the most common software used to codify knowledge, IT-tools used to share codified knowledge and different databases used to store codified knowledge are summarized below. This is done in order to illustrate the scattered routines.

Software used when Codifying Knowledge for Storing as Separate Documents

- Excel
- Word
- Power Point

IT-tools used to Share Codified Knowledge

- E-mail
- Lotus Notes
- SharePoint
- To some extent, SMS

Some Databases used to Store Specific Codified Knowledge

- Design information
- Commercial information
- Test data
- Market information
- Configuration information

4.2 Knowledge Reuse Capability

It is stated that the company is poor when learning as an organization. When considering the evolving knowledge exchange in the organization, the situation is complicated, typically due to the importance of being up-to-date with new technology trends. And in periods when seniors retire, it is apparent that the knowledge base in the company is negatively affected. As they leave, the experience and knowledge, hold by seniors, leave with them. This has affected the business largely at times, in the sense that *"the wheel has to be reinvented"* by juniors. This may be due to a lack of awareness of established designs, or an unwillingness to utilize them. It may also be due to insufficient knowledge reuse, passing from experienced developers to young developers.

Below a short summary of issues considering the knowledge reuse capability at the company are presented:

- Routines for codifying knowledge
- Subjectivity when using someone else's codified knowledge
- Habits for utilizing knowledge
- A difficulty in finding the right knowledge – which may be due to restrictions in present software systems, where the usability is limited by high control, which incorporate complications in documentation and when locating knowledge. It is stated; *"I want to be able to drag needed information from the system into a new context"*, meaning that the knowledge may be stuck in the systems' restrictions.

4.2.1 Routines for Codifying Knowledge

It is stated that it is difficult to get meaningful knowledge out of the loads of statistics and different documents found in the systems.

"Information that is coded properly, becomes knowledge"

It is also stated that, in situations when knowledge is needed fast, a "cheat sheet" is used, where some "how" and "why" are explained, which can be useful in decision-making. However, this "cheat sheet" is limited in the richness and flexibility of maintenance. In relation, it is said that it is important to disseminate relevant knowledge. However, what is relevant for one person may not be relevant to another, making this process difficult.

"We have no common standard between departments, which is a problem"

In some departments, checklists are typically used for memory support and to recognize deviations. When creating a checklist it is stated that, if it is formed before you meet a problem, you know how to act when it arises. However, if you create a checklist while in the problem, it is easy to "not see the forest for the trees".

"You may get an over-trust in marking the list, thinking that the actual work is to just fill out the checklist"

Bureaucratic structures are used to regulate the documentation. There are identified issues regarding routines and the complexity of software. There is also a lack of flexibility. This inflexibility might affect the richness of the explicit knowledge. However, the regulation can be important in the sense that no juxtapositions will appear and confuse the knowledge recipient. The setting can arguably be defended by the want to ensure a small gap of subjectivity.

4.2.2 "Lessons Learned"

Within, as well as between, projects, it is recognized that "lessons learned" are seldom utilized, even though the benefit of utilizing them are known. There is apparently strict regulation on documentation of projects and lessons learned. However, it is said to be difficult to make a good summary of "lessons learned" – *"there is more knowledge in the brains of individuals than in their documentation"*. Thus, knowledge is claimed to be lost in documentation. It is also stated that management has changed several times and that this affects the routines and the learning environment.

"Every project writes the same lessons learned, so we do not learn as an organization"

It is said that there is no one with a holistic view of the whole lifecycle. And due to the knowledge reuse routines "the wheel is reinvented". It is said that if a new component of an existing one is redeveloped, *"we assume that there is a need to design a new component"*.

"If we fix something how do we remember 5 years from now?"

It is argued that well documentation, teaching and giving the opportunity to hand over is important. It is well known that there is too little structured knowledge recycling. It is however also stated that it may be due to the complexity of such a recycle, and the dependence of a knowledge context. To be able to make a "lesson learned", you need to control all possible context variables.

4.2.3 Unstructured Software Systems

In the company information systems, copious amounts of information are available, however it is generally rather unorganized. This typically implies that the explicit knowledge largely may be classified as data.

"All the information is available, but the landscape of the systems is as scattered as the organization"

The systems are very difficult to use. This may be due to the fact that there is no central instance where knowledge is stored. The systems are built up by functional area, which cause complications when accessing knowledge from other departments. However, within each functional area, it seems to be easier to find information and knowledge, whilst you have learnt how to use the systems. Efforts are occasionally made in trying to make the systems orderliness, but it does not take long before it becomes chaos again. Above all, the search engines are very poor.

"If you know where too look the information is there, but how to retrieve it and how to find it is a challenge

When two very sensitive, opposing, decisions are taken and codified, and knowledge for some reason is not reused, failures may occur. When knowledge is needed from other departments, it is difficult to find it. There are different databases in different functional areas. It seems that it is easy to find knowledge within the department, but due to different codifying routines, it is difficult to go beyond ones functional silo.

4.3 Knowledge in Different Product Development Phases

It is said that the need for knowledge differs between different product development phases. In some phases, more detailed knowledge is needed to make decisions on for example choice of material etc., and in other late phases you need to see the holistic perspective, when considering for example logistics and production processes.

It is stated that market input is important in early development phases in order to understand the user needs and wants. However, it is also recognized that it is difficult to get a hold of the knowledge needed in early phases. It is supposed that when knowledge cannot be found in early phases, it leads to product changes in later phases of the development. This may be a matter of not reusing knowledge, starting a new project without looking in the rear view mirror. In research and development there is a need to know what the customer and the user truly need and want. Actually, one root-cause to poor knowledge reuse patterns may be misunderstandings between departments. By understanding that the whole organization benefit of knowing what the customer need and want, the technical requirements may be defined out of that, which implies that a cross-functional setting may encourage knowledge reuse between projects and departments.

4.4 Too many Meetings may be Counterproductive

In the company, there are a lot of meetings on a daily basis. In meetings, problems that occur and upcoming activities and are typically discussed. Generally, meetings are held within small groups of about 8 people. The meetings is said to result in producing new material for the organization. It is also stated that it is important to get the right knowledge and to be synced in the organization to add value for the benefit of the customer. After observing daily work, it was recognized that there is a common absence of people in the organizational landscapes, where knowledge, according to a lot of the interviewees, is shared through social interactions. One employee replied when questioning the absence of employees, *"I am off for another meeting, it is how we work here"*.

From the interviewees' experience it is recognized that many late product changes may be caused by misallocation of knowledge and information in early phases. These product changes may trigger conflicts between functional departments and between projects. This may contribute to the large amount of meetings, where conflicts, due to the late product changes, need to be solved. This may be largely counterproductive and implies a need for wider cross-functional setting.

5 Discussion

In this section, the literature review and empirical findings are set into a context of particular topics of interest. The findings are deliberated and comprehensively formed into a holistic perspective, related to the research questions found in section 1.3.

5.1 Knowledge are Bound in Companies' Solutions

Typically, knowledge may be seen as experience or interpreted information. However, knowledge can arguably be bound into the companies' solutions. Meaning that companies should not only reuse knowledge as in people's memory base, but also reuse product components and other solutions. In this sense, waste, explained by the concept of Lean, may also be defined as not making use of existing solutions.

5.2 Factors that may Affect Knowledge Reuse

The empirical study largely verifies what is typically found in literature, namely that knowledge management efforts are unevenly recognized. Meaning that there are several issues concerning how knowledge reuse is taken into account, specifically between projects and departments. To illustrate this paradigm, a few representative citations from the interviews are discussed more in depth.

- ***"We have no common standard between departments, which is a problem"***

  This may indicate lack of routines and lack of standardized knowledge reuse methods used between departments. How this issue could be addressed may vary due to the present organizational setting and how product development projects are set up. For example, a cross-functional organizational setting is specifically effective in early product development, if considering set-based product development, since knowledge will be put together from different departments into viable concepts. This also denotes that one does not only need to recognize a single organizational change, i.e. set standards of knowledge reuse methods. One should rather consider several organizational changes, aiming for a greater elaborated vision, in order to fulfill prosperous knowledge reuse.

- ***"You may get an over-trust in marking the list, thinking that the actual work is to just fill out the checklist"***

  The overall culture of not asking, rethinking or reflecting upon the work done, employs habits and individual behaviors that denote a need for change towards i.e. a Lean approach, where one needs to be critical, yet open, towards what, of the work done, can be made differently and why. The Lean approach is presented more in depth in section 3.4. Also, in efforts of change, leadership is prior. Thus, without any rigorous persuasive properties of stressing why the

change is important and how it will affect all involved, one will never succeed in the change implementation.

- ***"Every project writes the same lessons learned, so we do not learn as an organization"***

  In product development, the value of reusing knowledge is massive, in terms of future success on the market. For example, "time to market" may be significantly shortened, due to a high availability of existing knowledge, whilst the wheel does not have to be reinvented over and over again. In this sense, the organizational culture may include habits of either utilizing knowledge or not utilizing knowledge. What is chosen and why?

- ***"All the knowledge is available, but the landscape of the systems is as scattered as the organization"***

  As one may recognize, terms of organizational culture and habits are typically stressed, however it is also important to recognize supportive solutions in knowledge management, such as information systems. In this case, the organizational landscape is brought into the landscape of the information systems, which may constrain the process of utilizing knowledge – knowledge that actually may be available.

- ***"There is more knowledge in the brains of individuals than in their documentation"***

  It is difficult to codify knowledge. This is actually the main reason for why the process of managing and performing the codifying process is as important as it is stressed here in this report. Thus, due to the difficulty in codifying knowledge, one need to engage efforts to attain positive results of a well implemented knowledge reuse methodology.

In the learning methods explained by NTL Institute for Applied Behavioral Science (2013) in section 3.3, two important factors in the creation of a learning process can be identified.

- The structure in proposing knowledge
- The persuasive factor of the propositioning

From this, an environment of spreading knowledge fast and simple can be established. Individual involvement as in reflection and rethinking should be premier. In accordance, it may also be important to construct a mentorship, letting experts be a support in the learning process.

The statement, *"the knowledge holders' ability to structure knowledge and express it convincingly affects how recipients will make new knowledge of it"* is interesting since it is these influential properties that make the recipient motivated, which in turn makes the recipient to rethink and reflect upon the material critically. Essentially, it is generally stated that individual reflection is a key factor to prosperous knowledge sharing. Due to this, standardized knowledge reuse methods may be applied to have a

predetermined structure for small space for subjectivity, high transferability in terms of elaborated pedagogy, easy access of knowledge, easy maintenance and update, as well as easy recognition, yet retaining flexibility.

5.2.1 Knowledge Reuse and its Boundaries

At the company where the empirical study was conducted, it seems that there is an unintentional disregard for managing knowledge reuse, which verify theory stating that large enterprises shows these patterns. In this sense, product development initiatives may not only be financially affected by customers' willingness to purchase the company's products, or costs such as of production or marketing, it indirectly also involves costs of poor knowledge reuse. Thus, if knowledge cannot be found, or is not utilized in early phases of product development, it typically leads to product changes in later phases of the development. These many late product changes may be caused by misallocation of knowledge and information in early phases and this, in turn, may be a matter of not reusing knowledge. This can be described by "starting a new project without looking in the rear view mirror". The unintentional disregard of poor knowledge reuse may be due to:

- **Knowledge reuse methods**
  Complex, and occasionally irregular, ways in which knowledge is transferred explicitly may contribute to low capability of knowledge reuse

- **Locating knowledge**
  The knowledge may be difficult to find, possibly due to unstructured systems for storing and accessing knowledge or that people who possesses specific knowledge are unavailable

- **Organizational culture**
  The organization in itself may not encourage reuse of knowledge as a logical and recognizable behavior

- **Individual behavior**
  Considering the fact that documentation from other projects are not utilized, one can argue that it is the intriguing concept of getting rid of past project and start a new one is in every persons psychological wellbeing, *"it is pleasant to feel that you create something new"*. However, one may also claim that the disregard of reusing knowledge is unintentional, being a matter of deeply rooted, learned, behaviors

5.2.2 Quality of Codified Knowledge

When considering how to implement knowledge reuse methods into the context of the knowledge value stream, described in section 3.4.4, time may be a decisive factor. Time has to be engaged into the codifying process, and the reuse of knowledge has to be considered as a delivery out of a project. However, unless the time is well spent, in terms of proposing the knowledge well, from holder to recipient, the process of codifying may be useless. In this sense, one can reason that time and quality are parameters to consider when codifying knowledge.

5.2.3 Refining Knowledge Reuse Methods

In order to present simple knowledge reuse methods, interactive visualizing products, such as smart tablets may be utilized. By reaching knowledge from another part of the organization, by removing middlemen, an "open street" between knowledge holder and knowledge recipient may be created. This could essentially be done and lower the influence of time-consuming and inefficient meetings, while knowledge will be retrievable at all times. This puts a lot of pressure on management, and the managing of codifying processes, as well as the software.

When developing a digital knowledge reuse platform for flexible use, focus should apparently be set on user friendliness, especially when maintaining or updating the content. It should preferably be maintained and updated together with the creation of new knowledge, providing benefits for the organization and business as a whole, inline with the company vision. This proposed flexibility may also be a key point from a learning perspective. Thus, when the content is updated, one needs to reflect upon the material and indirectly prepare the material for "teaching" others, which contributes to the highest knowledge retention (NTL Institute for Applied Behavioral Science, 2013).

While suggesting knowledge reuse methods, it is important to remember that social interactions also have a vast part of prosperous knowledge reuse. All knowledge are not suitable for codifying, such as the intelligence based tacit knowledge explained in section 3.2.2. Knowledge reuse methods should in this sense rather be seen as a support, where certain knowledge are available at all times, even if an employee retires, go away for vacation, or similar. Also, the use of social interactive support, including bouncing ideas between individuals, are vital for gaining mutual understanding, creating new knowledge and inspire innovation. However, this study is not about the creation of new knowledge, it is rather the process of reusing existing knowledge.

5.2.3.1 Maintaining and Updating – Example: Check-sheets

In managing knowledge reuse, efforts may be infused by concepts such as

- **Practice by doing**
  The knowledge recipient imitate what is demonstrated
- **Immediate use of learning**
  The knowledge recipient imitate interactively

And, due to the stated importance of reflecting in understanding and learning, "check-sheets" may be contextualized in an interactive environment, preferably for simple use and update framework in touch-screens. Accordingly one may consider that the knowledge recipient becomes knowledge holder, as in:

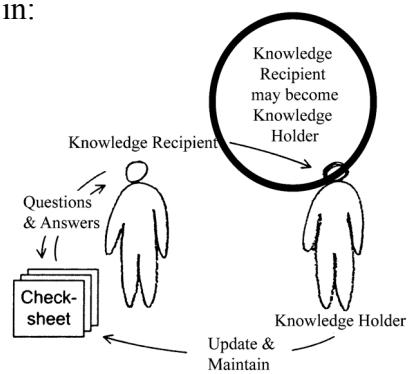


Figure 12. Altered version of working with check-sheets, where the knowledge recipient may become knowledge holder (adapted from Holmdahl, 2010).

The setting of continuous knowledge capturing may contribute to a learning organization, where the responsibility for the codifying process is altered. However, the process has to be infused by mentoring, in order to not loose quality in the maintaining and updating process.

5.2.3.2 General Approach on Learning – Example: LAMDA

The LAMDA process is, in accordance to the Lean concept, a general approach on learning from what can be seen or done. In order to keep knowledge flourishing in a company, and not be left unutilized, companies should consider creating a roadmap towards prosperous knowledge reuse. In order to be inspired by ways of working with knowledge reuse methods, a strategy for methods and performance is proposed in "Interpreted LAMDA Process for Knowledge Reuse" found in Appendix.

5.3 Cross-Functional Setting Benefits Critical Knowledge Flow

One function in a company may recognize another function as an obstacle, preventing them from doing their work. Design engineers might consider manufacturing engineers as obstructs, when receiving feedback for a design being impossible to manufacture, whilst manufacturing might consider design engineers wasting their time designing something impossible to produce. A cross-functional setting is meant to solve these issues, however at first it may seem frustrating. In order to solve arising conflicts, the functions need to communicate with each other. Additionally, the authority may change throughout a project. In an early phase one function, such as market initiatives, may be more important than manufacturing. However, this does not indicate that manufacturing does not benefit from being involved in early phases; one may argue that it is rather the opposite. By understanding the market and gain knowledge from other departments, and reuse knowledge from other projects, the phases from research to manufacturing linking all life-cycle aspects together into a holistic perspective. This approach may create a more flexible organizational environment in the sense that it, in best-case scenario, is highly responsive to market changes. As a suggestion, market initiatives may start a LAMDA-process and try to understand manufacturing processes.

The hampered knowledge reuse capability at the company may be due to the company's narrow and functional knowledge distribution setting, thus a lot of the empirical data indicates a need for a wider cross-functional setting. The idea of cross-functional setting may also permeate the structure of information systems, to gain a less scattered organization also when considering the searching in the systems. Additionally, a cross-functional setting would enable a culture of less wasteful conflicts between departments and a higher capability of knowledge reuse. Primarily, cross-functional setting may arguably be most suitable in early product development phases, when the need for knowledge, according to interviewees, is at its maximum.

In literature it is thoroughly stated that departments such as marketing, research and development, design and manufacturing should work closely together. It is therefore a striking concern that there is a disregard for letting departments cooperate. Some claim that not all of these, according to practitioners, highly involved departments need to understand or know about customer and user needs and wants. In general, it may be said that without this input of knowledge, flowing through the company, there will be an evident difficulty to design and develop offerings that the customer and

user need or want. Responsively one can recognize that the greatest waste of them all is to develop products that no customer need or want.

Having a combined spread of knowledge as in cross-functional setting may minimize the risk of project failure. Cross-functional setting may also encourage individuals to break old habits, while creating the same standards and a culture to be spread throughout the organization. However, some may find it peculiar to be working cross-functionally, why negative attitudes may arise. This can affect the work and puts high pressure on leadership.

Technology advances, the amount of functions integrated in product offerings are increasing and market competition level is rising globally. However, it is important to note that cross-functional setting may not be an ideal solution for all product development projects, although, it may be an environment of high capability of knowledge reuse.

5.4 Further Areas for Exploration

In relation to this study, it is interesting to see what may be studied even further. For example, face-to-face interpersonal interactions and the influence of body language in learning should be essentially considered and further analyzed. Though, social interactions, in the sense of sharing ideas, might be somewhat implemented in a knowledge reuse process, where social interactive media may be an inspiration. Additionally, the design of for example A3 reports or check-sheets are also intriguing for further consideration and analyze, where fonts, spacing, choice of illustrations and the whole composition of the propositioning may contribute to the factor of persuasion, which in turn may motivate the recipient to address the knowledge content more carefully. This may seem very fuzzy, but considering the importance of motivation, these aspects may be extremely important.

In accordance to this, it is important to notice that a knowledge reuse method cannot be totally generalized. It should rather be developed by means of the specific task, whereas standardized methods are keeping subjectivity at a low level. However, some flexibility may be offered. The practices proposed here can however work as a guide when refining a knowledge reuse method and outlining essential operations in interactive learning processes.

5.5 Sustainability, Ethics and Knowledge Reuse

The world is lacking reserves, and global warming is a well-known phenomenon. What partly contribute to these occurrences are redundant product development efforts. The means for more efficient practices in industry is therefore of great significance. Thus, products ought to be developed without unnecessary changes. Product changes may also contribute to unnecessary scrap, scrap that in certain contexts may be customer value. Efforts on knowledge reuse, or reuse of any resource, may therefore contribute to a better understanding of the fuzzy internal consequences of low knowledge reuse. If companies do not consider these elements, such as being sparse with resources, the ethics are in the hands of the implementer. Though, this thesis only proposes practices for indirect sustainable and ethical means.

6 Conclusions

This section is focused upon answering the research questions stated in section 1.3, by combining all content, literature review, empirical findings and discussions. In this sense, it is worth noting that the answers are under a question of subjectivity.

Q1: What are the critical mechanisms for prosperous knowledge reuse in product development?

It is important to notice that the methods used for making knowledge reusable are not solely concluding a single straightforward solution. Below, the main mechanisms for prosperous knowledge reuse are presented.

1. **Knowledge Reuse Methods**
    - Standardize methods for low subjectivity
        - Structure and persuasion – use illustrations and short describing text
        - Recognizing structure is important for understanding and comparing

2. **Performance of Managing Boundaries**
    - Routines for codifying knowledge
        - Plan the codifying process
        - Engage time into the codifying process
    - Rethink and reflect upon the quality of codified knowledge
    - Establish easy locating systems for easy storage and access of the codified knowledge

3. **Leadership and its Influence on Knowledge Reuse**
    - Encourage knowledge reuse, and let it saturate the organizational culture
    - Consider cross-functional work as a way of support in knowledge reuse between projects and departments
    - Mentoring for enabling social support and infuse a culture of rethinking and reflecting

Waste in Product Development
In accordance to prosperous knowledge reuse, and the lean concept, the company's focus may be set on eliminating waste. Below, some sources of Product Development waste, described by Mascitelli (2007), are presented, followed by a description on how they may relate to knowledge reuse.

- **"Chaotic work environment – constant interruptions"**
  May be eliminated by high capability of managing knowledge reuse while supportive solutions do not put as high pressure on people's availability.

- **"Lack of clear prioritizations of projects/tasks"**

May be eliminated by working with lessons learned, where knowledge from other projects may indicate how to prioritize.

- **"Poor communication across functional barriers"**
  May be eliminated by cross-functional setting and knowledge reuse between departments and projects.

- **"Poorly defined product requirements"** and **"Disruptive changes to product requirements", and "Lack of early consideration of manufacturability"**
  May be eliminated by for example work with check-sheets, where the company's manufacturing capability is presented and with support of other knowledge reuse methods that may ease the understanding of customer and user needs and wants. However, this also puts efforts in the gaining of customer and user data. Also set-based design (described in section 3.4.5) and cross-functional setting, where market input should nurture all departments are of consideration.

- **"Overdesigning, analysis paralysis, gold-plating"**
  May be eliminated by encouraging reusing solutions and components as in bound knowledge.

- **"Too many @!%&* meetings"** and **"E-mail overload"**
  May be eliminated by efficient management of knowledge reuse and cross-functional setting. At least, unnecessary meetings may decrease, however meetings due to cross-functional efforts may increase.

Q2: Which methods are most suitable for knowledge reuse?

There is no "one method fits all" when considering knowledge reuse. It is rather a matter of the transferability that determines which method to apply. This puts pressure when outlining which method to use, and in the creation of new standardized methods. If a method is wrongly determined inline with the transferability, it will be difficult to process and codify the knowledge, thus knowledge may be wasted. In this sense, it is important to consider what knowledge future users might need. Likewise, it is equally important, when the standards are set, to determine the transferability of the knowledge and choose a suitable method for the purpose. In this case, while introducing the standards within the organization, initial mentoring or well-designed guidelines may be decisive for future choices of which method to use by employees. In this sense, a summit in the end of a project may be of great use. The project may be discussed from the perspective of what knowledge is important to reuse in future projects, why it is important to future users, who would benefit from such knowledge and then the team may decide how to codify it. While, in this process, it may also be of great use to specify who is responsible for the codifying of the knowledge, in order to complete the codifying process before a new project begins. However, it is not merely useful to consider a summit in the end of a project. Companies should consider codifying knowledge continuously, since knowledge could be lost if not codified instantly. A proper guideline for this approach would be of great use.

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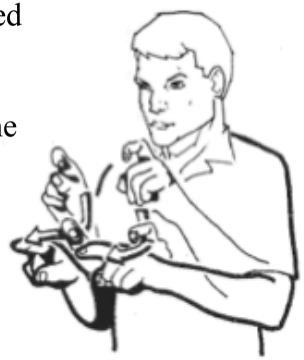
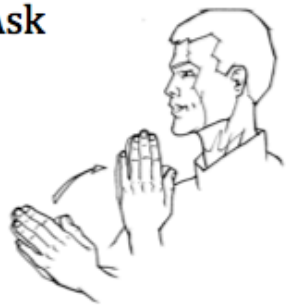
Interpreted
LAMDA Process for Knowledge Reuse



- Make the changes discussed and,
- Store the codified knowledge and make it easy accessible for the members of the organization

- *What knowledge, of what I have learned, am I codifying?*
  - What is the essence of the findings?
- *Why am I codifying this knowledge?*
  - Are there any good reasons why to reuse this knowledge?
  - What are those reasons?

Act → Look → Ask → Model → Discuss → Act



- *Who, in the organization, would benefit from this knowledge?*
- *How will I codify the knowledge?*
  - Define the transferability: tacit to explicit, or explicit to tacit
  - Choose knowledge reuse method

- *How will the recipient interpret the codified knowledge?*
  - Discuss and verify the codified material with someone else, preferably someone outside the department or project
  - *What can be done differently?*
  - *How can it be done differently*

- Codify knowledge