UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCUELA TÉCNICA SUPERIOR INGENIEROS INDUSTRIALES VALENCIA

DEVELOPEMENT OF A KNOWLEDGE BASE FOR KNOWLEDGE REUSE IN DESIGN PROJECTS. MINI'S INTERIOR DESIGN AS A CASE OF STUDY

AUTHOR: PAULA MARÍA MONTESA RAUSELL

SUPERVISOR: MIGUEL ÁNGEL ARTACHO RAMÍREZ

SUPERVISOR: CRISTINA CARRO SAAVEDRA

Academic year: 2016-17

CONTENT

DOCUMENT 1: PROJECT MEMORY

DOCUMENT 2: BUDGET

DOCUMENT 1: PROJECT MEMORY

Table of content

1. Introduction 4

1.1 Current situation 4

1.2 Motivation and objectives 5

1.3 MyMINI Project 6

1.4 Structure and methodology of the thesis 7

2. State of the art 13

2.1 Knowledge in engineering design 13

2.1.1 The role of knowledge in companies 13

2.1.2 An overview of knowledge management 15

2.1.3 Knowledge reuse in engineering design 17

2.1.4 Challenges and perspectives of knowledge reuse 19

2.1.5 Types of knowledge 22

2.2 Definition of knowledge base 27

2.2.1 Purpose of a knowledge base 27

2.2.2 Current knowledge bases and their limitations. 27

2.2.3 Requirements and challenges of knowledge bases 31

2.2.4 Knowledge to create a Knowledge Base 36

2.3 Lessons learned 47

2.3.1 Types of lessons learned 47

2.3.2 Extraction and use methodologies 49

2.3.3 Role definition 50

3. Analysis of the team and its work 51

3.1 Presentation of the team and its objectives 51

3.2 Introduction to the agile methodology 52

3.2.1 Scrum as tool 53

3.3 Knowledge generation 55

3.4 Role of the knowledge expert 57

3.5 Requirements for a knowledge base in agile projects 57
3.5.1 Feedback from the team regarding their current knowledge repository 58

4. Creation of a knowledge base 60
4.1 Set of requirements for the project knowledge base 60
4.2 Definition of the metadata 62
4.3 Definition of the ontology 64
4.4 Definition of the connections 69
4.5 Analysis of the complete design 70
4.6 Implementation of the Knowledge Base 72
4.7 Examples of its use 76

5. Automatic retrieval through parameters of design situation 80

6. Lessons learned sessions 84
6.1 Development and results of the first lessons learned workshop 84
6.2 Development and results of the second lessons learned workshop 93

7. Evaluation of the knowledge base 109
7.1 Evaluation methodology 109
7.1.1 Feedback. Document registration 110
7.1.2 Feedback. Knowledge base usage 111
7.2 Evaluation of the requirements achievement 115

8. Evaluation of the lessons learned sessions 119

9. Discussion of the research methodology 122

10. Conclusion 125

11. Summary and future work 127

12. Bibliography 129

13. List of figures 136

14. List of tables 139

1. Introduction

1.1 Current situation

In the global world of todays, where markets are completely internationalized, the environment changes rapidly and the competition is stronger than ever; companies struggle to gain and keep competitive advantage. Since the internet and communication media have allowed the information to be global and effortless obtainable, most companies have access to the same processes and management systems, becoming the intellectual capital the one remaining to make a difference between companies' performances (Wiig 1997).

In time of Knowledge Age, people are realizing that knowledge is power. Past knowledge can support the decision making process, avoid the repetition of mistakes and the time waste. Furthermore due to the poorly effective knowledge reuse systems, designers spend most of their time looking for existent solutions among complex knowledge repositories; instead of focusing on new properties and new knowledge generation, improving the quality of the product and its suitability to the customer needs (Salas, 2015, p.4). Balance between activities that should be optimized to encourage innovation and product improvement.

The practical motivation for knowledge reuse systems is that the capture and reuse of knowledge is less costly than its recreation (Fruchter & Demian 2002). To this end appeared the concept of knowledge management. A discipline whose purpose is to maximize a company´s knowledge reuse. Knowledge management is the *"process of capturing, developing, sharing and effectively using organized knowledge"* (Koenig 2012). The focus is then to support the knowledge sharing and creation, making this way possible a company intellectual growth.

Keeping this purpose in mind, several researches have worked on the topic and established different knowledge management processes to make the use of this resource possible. Nevertheless, valuable knowledge still gets lost. Whenever an idea or background of a decision is not well understood and properly externalized, knowledge will be lost.

1.2 Motivation and objectives

Being knowledge reuse one of the most important phase of knowledge management processes, few studies about this phase are to be found in the existent literature. On the one hand, it is commonly but wrongly assumed, that once the knowledge is properly stored, its reuse is going to happen automatically (Schact & Maedche, 2016). On the other hand, the effects of applying knowledge reuse systems are difficult to measure (Cohen 2006). Only recognizing if knowledge reuse is being applied is not an easy task; but even more challenging is to quantify the impact that this has on an employee's work or on the customer perception of the service received. This vagueness relating the impact measures makes it almost impossible to translate knowledge reuse application into a profit increase. Therefore little attention is being paid to this phase and knowledge stills get lost.

Companies around the world spend time, effort and money trying to incorporate into their systems the most efficient knowledge management systems. Not only software tools are considered, but also cultural and strategical aspects. Nonetheless knowledge reuse doesn't get to happen or at least the desired results are not met.

Moreover a recent COVEO study claims that the vast majority of engineers work around a 75% of their time in issues that already have been solved within the company. The same study concludes that the company profitability could increase up to a 50% if engineers could be able to access more and personalized knowledge. These statistics reflect the current problem that engineers face when looking for knowledge and state that providing a better knowledge access at the point needed would have a multiplicative effect, which extends far beyond the linear time saving. Knowledge workers could upskill while working, being able to work on higher-level tasks and even to create new knowledge.

If already in general terms knowledge reuse literature is scarce, the one addressing engineering design is almost inexistent. Engineer designers point out that current knowledge reuse methodologies are very narrow to approach the whole process development; furthermore they are just suitable for some project stages. Most of the times, the knowledge found is exclusively focused on geometrical data, which is easier to store, but often not applicable in early design stages. Non-geometric knowledge such as problem solving methods, solution generation strategies, design intent and project knowledge should also be developed and further explored, as these knowledge types are associated with the variety of tasks in today's dynamic design processes. Nevertheless the documentation effort of these kind of archives is much intense as they require a knowledge processing action (Baxter et al. 2007).

The need to support designers, with the required knowledge along the different project phases is the driver of this work. Therefore, the question to be answered through the following chapters is how knowledge bases of design projects can be created, in a way that they can be efficiently used in future design projects. In order to approach this unknown, the purpose of this thesis is to cover the subject in the following ways. Firstly, by analyzing the general requirements of engineering design projects and their knowledge reuse systems. Secondly, by working in a real design project, to bring perspective to the literature findings and this way be able to implement a system that satisfy both the theoretical and the real problems of design engineers. Lastly the evaluation of the implemented base will establish the first steps for the improvement of the system in following researches and will help to validate or invalidate some of the literature hypothesis on which the current work is based.

1.3 MyMINI Project

As mentioned before, to make this thesis possible, working in a real engineering design project was necessary. This was the only way to experiment in my own flesh how their work is and so better understand their requirements, wishes and problems when it comes to knowledge management and knowledge repositories issues.

The project is called *MyMINI Project - Agile product development in highly complex development processes*. MyMINI project takes place in the Garching Campus of the Technical University Munich. It is led by the chair of product development (PE-Lehrstuhl) with the collaboration of some members of the BMW Group.

The aim of the project is to bring a group of students together to generate innovative ideas for the interior of a MINI. The ways of proceeding that the team must follow are various start-up methodologies, as the aim of the project is to proof that even big enterprises can react in an agile way to the customer requirements (Böhmer et al. 2016).

Acting as a start-up involves responding quickly and based on customer feedback. That means for the engineers, lots of iterations and redesigns according to the validation or invalidation of their previous hypothesis. The purpose of the methodology is generating innovations by understanding and involving the end user in the whole process.

The team who will execute this work is compound of ten students that will generate the new ideas, proceeding in the way already explained, while supporting the common work with their individual thesis in different relating fields.

This project is a great opportunity to experiment the situation that designers in first stages of innovative projects have to face, and this way analyze how their knowledge requirements differ from structured and very well-known development projects.

Figure 1-1: Some members of MyMINI project – MINI Cooper borrowed for the project

1.4 Structure and methodology of the thesis

The structure of this thesis is divided in four blocks according to the work of Blessing and Chakrabarti (2009). Thorough this thesis, the knowledge reuse problem will be approached with the final objective of implementing a knowledge base capable to fulfil the requirements of the current design engineering teams. The division of this work in four blocks will help us to cover every topic of the problem and assess it in a scientific way.

Beginning with the ***Research Clarification*** part, ***chapter 2.1*** pictures the current situation of knowledge management systems and knowledge reuse in present companies.

Chapters 2.2 and 2.3 expose the key factors for succeeding in the implementation of both a knowledge base and the lessons learned sessions. ***Chapter 3*** will introduce MyMINI as an agile engineering design project and will help to give shape to the requirements of the base attending to their particular working methodologies. This chapter clarifies the reader the thesis and project context and helps defining the success criteria to be afterwards evaluated. These chapters will then cover what Blessing and Chakrabarti call the ***Descriptive Study I***.

The next block contains the ***Prescriptive Study***. In ***chapter 4*** the knowledge base solution will be introduced and its implementation explained. ***Chapter 5*** presents the concept of knowledge reuse situations and explains how different parameters regarding these situations affect the knowledge that should be provided to the users, for effective knowledge reuse to happen. The impact of these parameters in MyMINI Project's context will be analysed and a suitable searching methodology considering the most relevant parameters will be exposed. Then, ***chapter 6*** will reveal the methodology employed to run the lessons learned sessions, attending to the phase of the project and the different purposes of each session. It was decided to carry them out, as they are considered to be a success key for knowledge reuse. Moreover the lack of managerial best practices and recommendations for future projects being documented during the project encouraged its realization. Then the learnings and plans of action will be presented. This way, the basis for the evaluation of the knowledge base according to the features implemented will be set through this block; being the same done, for the examination of the success of the workshops and the learnings application.

Lastly the ***Descriptive Study II*** can be found. ***Chapters 7 and 8*** cover the evaluations of both knowledge base and lessons learned workshops. The implemented knowledge base is evaluated attending to different parameters and user cases, so that the previously defined success criteria can be judged. Moreover the satisfaction in the implementation of the learnings and the benefit of running lessons learned sessions will be approached. Finally ***chapter 9 and 10*** will come up with the discussion of the research methodology applied and the conclusions of the study. Bringing ***chapter 11*** some insights about the future work to be done in the field.

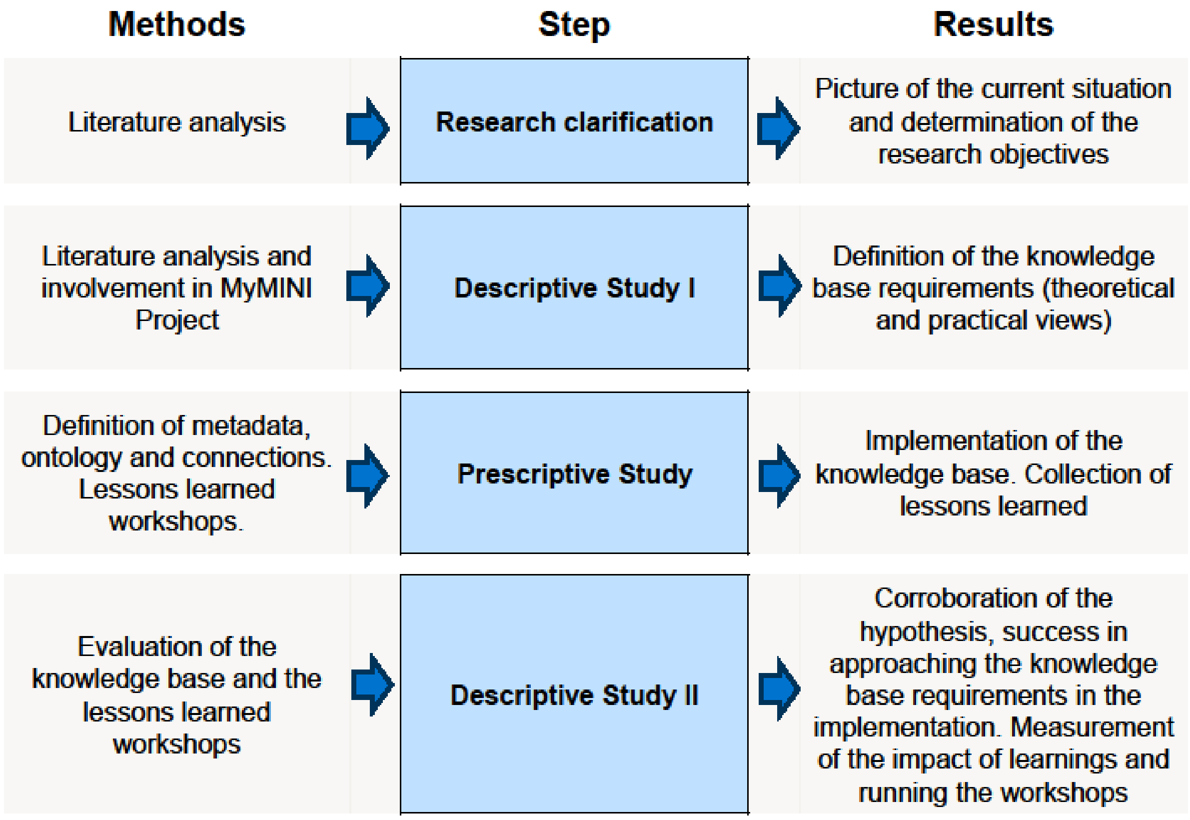


Figure 1-2: Overview of the research methodology followed in this thesis

To efficiently divide and carry out the work, the research steps will be translated into concrete phases and tasks. Table 1-1 represents all the activities involved in the project.

Table 1-1: Work breakdown structure of the project

		Duration	Start Date	End Date
1	**Organization**	**22 days**	**mon 02/05/16**	**tue 31/05/16**
1.1	First approach with the multidisciplinary team	1 day	fri 06/05/16	fri 06/05/16
1.2	First meeting with BMW experts and project tutors. Presentation of the project and definition of objectives	1 day	fri 13/05/16	fri 13/05/16
1.3	Acquisition of a global vision of the project	22 days	mon 02/05/16	tue 31/05/16
1.4	First readings about the topic	22 days	mon 02/05/16	tue 31/05/16
2	**Theoretical research**	**80 days**	**mon 16/05/16**	**fri 02/09/16**

2.1	Establishment of a literature search plan. Main terms identification	2 days	mon 16/05/16	tue 17/05/16
2.2	Search and collection of documentation	24 days	mon 16/05/16	thu 16/06/16
2.3	Literature reading	25 days	mon 30/05/16	fri 01/07/16
2.4	Second cycle of literature search and reading	35 days	mon 04/07/16	fri 19/08/16
2.5	Selection of relevant literature and entering citations in CITAVI	10 days	mon 22/08/16	fri 02/09/16
3	**Structuration**	**20 days**	**mon 04/07/16**	**fri 29/07/16**
3.1	Formulation of hypotheses and basic research questions	9 days	mon 04/07/16	thu 14/07/16
3.2	Content organization	15 days	mon 04/07/16	mon 25/07/16
3.3	Formulation of tasks and objectives	4 days	tue 26/07/16	fri 29/07/16
4	**Knowledge Management in MyMINI Team**	**95 days**	**mon 16/05/16**	**fri 23/09/16**
4.1	Identify the relevant generated knowledge	15 days	mon 16/05/16	fri 03/06/16
4.2	Sorting future documentation in knowledge groups	20 days	mon 06/06/16	fri 01/07/16
4.3	Determining attributes for the different types of knowledge (links)	10 days	mon 20/06/16	fri 01/07/16
4.4	Lessons Learned Workshop 1	1 day	fri 10/06/16	fri 10/06/16
4.5	Documentation and analysis of the Workshop 1	5 days	mon 13/06/16	fri 17/06/16
4.6	Lessons Learned Workshop 2	1 day	fri 02/09/16	fri 02/09/16
4.7	Documentation and analysis of the Workshop 2	5 days	mon 05/09/16	fri 09/09/16
4.8	Determination of the knowledge base requirements	21 days	fri 01/07/16	fri 29/07/16
4.9	Collection of documentation generated in the project	30 days	mon 01/08/16	fri 09/09/16
4.10	Implementation of the knowledge base in SOLEY	25 days	mon 01/08/16	fri 02/09/16
4.10.1	Introduction to SOLEY	2 days	mon 01/08/16	tue 02/08/16
4.10.2	Modification of the software's metadata according to the requirements of the base	7 days	wed 03/08/16	thu 11/08/16

4.10.3	Design of the main base structure. Nodes and connections	5 days	fri 12/08/16	thu 18/08/16
4.10.4	Introduction of documents and their attributes in the knowledge base	11 days	fri 19/08/16	fri 02/09/16
4.11	Evaluation of the operation of the knowledge base	10 days	mon 05/09/16	fri 16/09/16
4.11.1	Evaluation of the documentation process	8 days	mon 05/09/16	wed 14/09/16
4.11.2	Evaluation of the searching process	8 days	mon 05/09/16	wed 14/09/16
4.11.3	Evaluation of the achievement of objectives set	2 days	thu 15/09/16	fri 16/09/16
4.12	Evaluation of the development and subsequent impact of Lessons Learned sessions	5 days	mon 19/09/16	fri 23/09/16
5	**Draft**	**35 days**	**mon 22/08/16**	**fri 07/10/16**
5.1	First writing of the work	35 days	mon 22/08/16	fri 07/10/16
6	**Review**	**17 days**	**mon 10/10/16**	**tue 01/11/16**
6.1	Reading of the work by the tutor	5 days	mon 10/10/16	fri 14/10/16
6.2	Corrections and improvements	5 days	mon 17/10/16	fri 21/10/16
6.3	Second private reading	3 days	mon 24/10/16	wed 26/10/16
6.4	Latest corrections and adjustments of format and printing	4 days	thu 27/10/16	tue 01/11/16
7	**Delivery**	**11 days**	**wed 02/11/16**	**wed 16/11/16**
7.1	Print	1 day	wed 02/11/16	wed 02/11/16
7.2	Delivery	1 day	wed 02/11/16	wed 02/11/16
7.3	Preparation of the presentation	9 days	thu 03/11/16	tue 15/11/16
7.4	Presentation	1 day	wed 16/11/16	wed 16/11/16

As it can be seen, the whole project is divided into seven main stages which are consecutively subdivided into tasks.

Organization phase: First gathering with the team and the BMW experts. Acquisition of input about the project objective and first insight about the topic.

Theoretical research phase: Different cycles of literature searching and reading. Citations and selections of relevant literature are also in this phase considered.

Structuration: Formulation of the research hypothesis and questions, content organization and general planning.

Knowledge Management in MyMINI team: This phase covers the identification and recompilation of the generated knowledge, as well as the definition of requirements for the knowledge base, its implementation and the posterior evaluation. The Lessons Learned procedure and evaluation will also be performed in this phase.

Draft: This phase attends the first writing of the thesis.

Review: Different activities from readings to corrections and last format touch-ups.

Delivery: This phase corresponds to the handover of the written work and the oral presentation.

The definition of these seven phases with their specific tasks allows defining a plan of action and so better organizing the development of this thesis. Here the main stages, covering from May to November can be recognized.

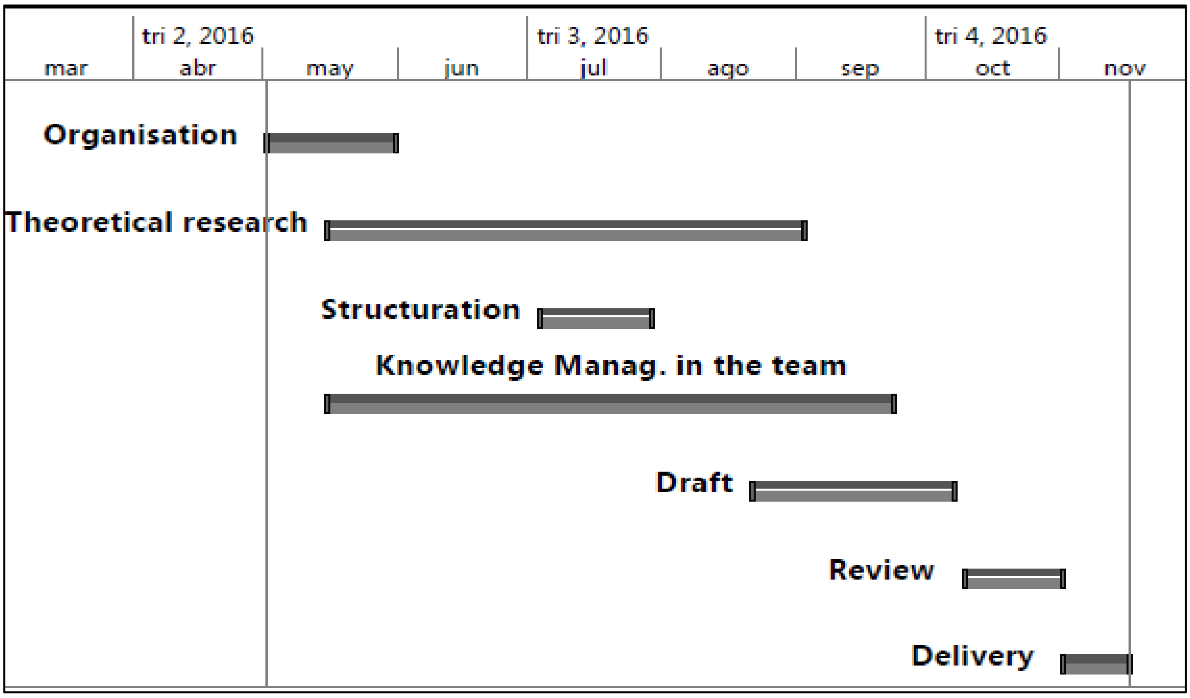
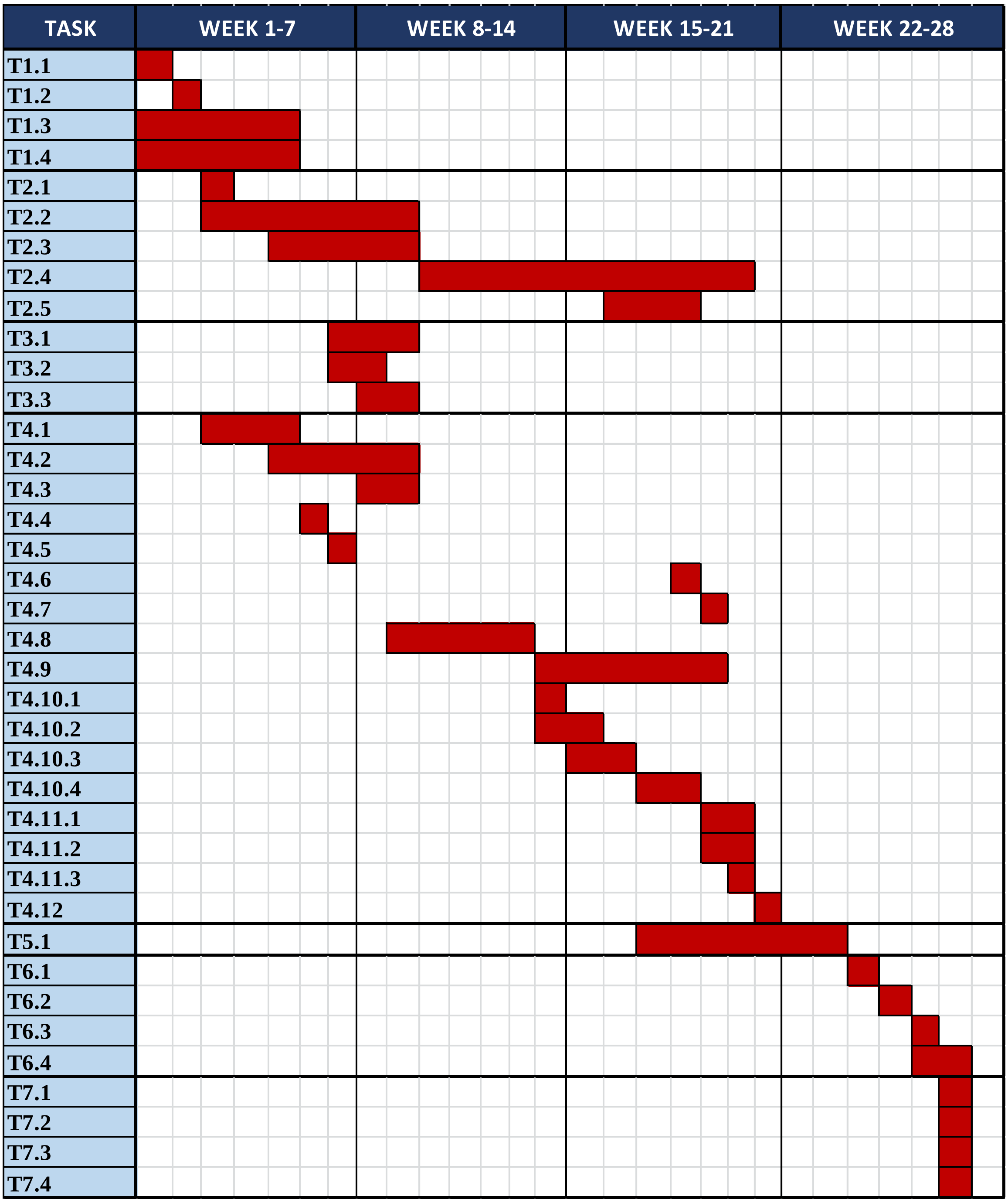


Figure 1-3: Gantt chart of the main stages

Table 1-2 shows how the main stages break down into the concrete tasks previously mentioned. The pseudo-Gantt chart depicted below shows how to orderly implement the different tasks to efficiently achieve the section's goals in the time set.

Table 1-2: Bar chart – Tasks breakdown among the 28 weeks



2. State of the art

The following chapter contains a general overview of the role of knowledge in the current companies, putting a focus in knowledge management systems and the knowledge reuse phase. The topics knowledge bases and lessons learned will be examined into detail, so as to clarify the purposes and requirements of both, to posteriorly implement a suitable solution.

2.1 Knowledge in engineering design

2.1.1 The role of knowledge in companies

Already in the early 90's, as company knowledge became recognized as an important asset for enterprises, and the concept of knowledge management appeared to safeguard this new realized power; several questions were brought to the table. What is actually knowledge? Is all generated knowledge valuable? Are data, information and knowledge the same?

Numerous researchers devoted their studies to come up with a general valid answer to all these questions. General answer that still today on focus, as several explanations have been developed but none of them can be fully applied in every field of knowledge.

Nevertheless, we can find in the literature pretty similar descriptions of the mentioned concepts. That is why for the purpose of this work, some of the most worldwide accepted definitions will be picked, to set a basis for the course work.

Ameri & Dutta (2005, p. 579) described data as "unorganized and unprocessed facts", while for them information can be considered as "an aggregation of processed data which makes decision making easier". Their definition of knowledge reads: "knowledge is evaluated and organized information that can be used purposefully in a problem solving process."

There is even a more accepted definition of knowledge. The one of Milton (2007), "Knowledge is the {ability, skill, expertise} to {manipulate, transform, create} {data, information, ideas} to {perform skilfully, make decisions, solve problems}."

Thus, it is discernible that data and information are easy to store, describe and manipulate; while knowledge requires a fully process of understanding and therefore is something active that can be created, transformed and actualized.

That leads us to the next point, why do we care in this work about knowledge management and not about information or data management? Well, given that data and information are easy to store, is common to find great amounts of cumulated data/information in every company repository and even if they weren't, the access to those in this "communication-era" is not a problem anymore. Contrarily, knowledge generation requires not only time but great expertise about the topic. Moreover, the process of generation is most of the times carried out in someone's mind and not externalized. Therefore, it is difficult to recognize whether new knowledge is being generated and this way be able to document the findings.

Hence, the process of knowledge generation can be understood as the natural development of processing data into information, and afterwards this one into knowledge. Requiring this last step a truly comprehension of the whole process (Figure 2-1).

Figure 2-1: Development from data to knowledge

Trying to make the most of the company knowledge appeared the discipline of knowledge management, understood as “the process of capturing, developing, sharing and effectively using organized knowledge” (Koenig 2012). Again knowledge management, because from what above stated, is knowledge the one that drives decisions and consequently plays a major role in the success of a company (Hicks et al. 2002).

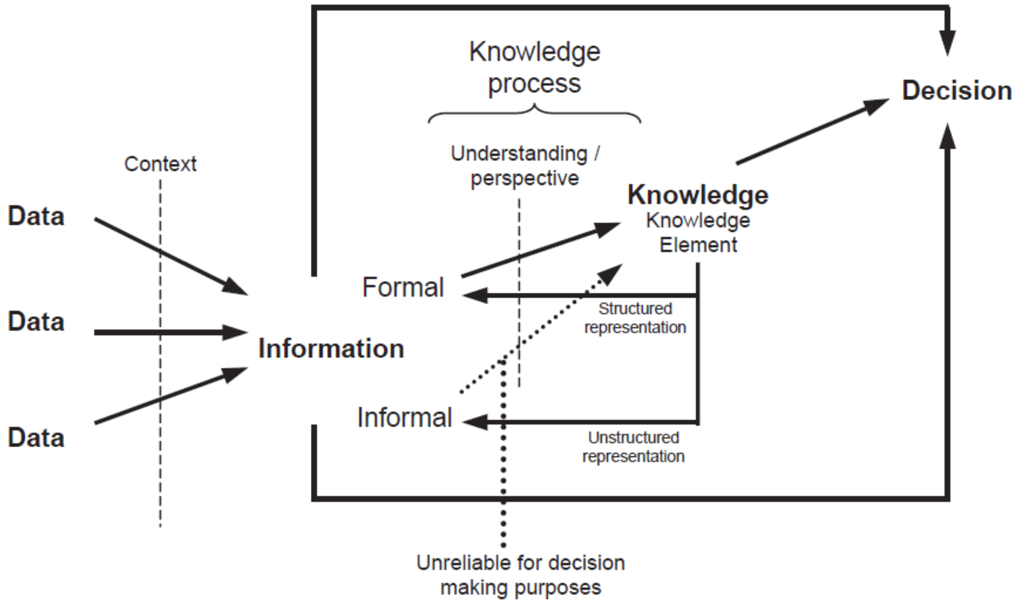


Figure 2-2: Relationships between data, information, knowledge and decision making (Hicks et al. 2002)

With the aim of creating value for the company, this system oriented approach claims to be not only an important companies’ success factor, but the key of innovation. By means of establishing learning routines, easing the decision-making process and stimulating a sharing culture; the production of new items, solutions and services is promoted. The only goal of managing knowledge is not to become more knowledgeable, but to become more aware of the possible solutions to problems which already exist and how to access them (Ling et al. 2008).

Considering our globalized world of instant communication, where product complexity and customer orientation grows by leaps and bounds, it is not difficult to figure out, the insistence of CEO's to ask for a more thorough and systematic management of knowledge (Staab et al. 2001).

2.1.2 An overview of knowledge management

As already stated, knowledge management is the *"process of capturing, developing, sharing and effectively using organized knowledge"* (Koenig 2012). The process itself is categorized by researchers in phases. However, the interpretation of these phases is not used consistently, resulting in confusion and uncertainty. Some examples are to be seen in figure 2-3. Unluckily not only are these categorization phases different but so are the meanings given to the names used. There is no consistency between the usages of terms like "Reuse" or "Application" among different authors.

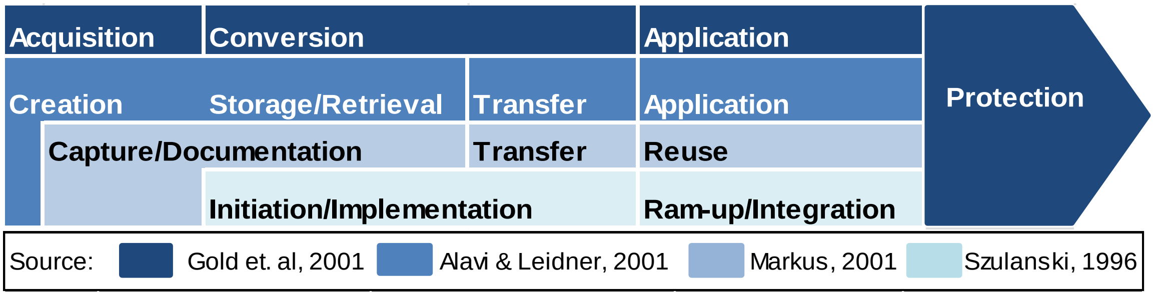


Figure 2-3: Knowledge Management process phases (Schacht & Maedche 2016)

Aiming to propose a general model for the knowledge management process, the work of Schacht & Maedche (2016) gathers the studies from several authors and combine their findings. Their model proposition can be broken down into the following five phases.

The first stage is understood as a ***knowledge acquisition phase***. By acquisition is meant both knowledge creation and knowledge search. When knowledge already exists, individuals just have to look for it in a given repository; when it comes to knowledge creation, a transformational process takes place. It is commonly accepted that knowledge can be explicit (it is possible to document it) or tacit (personal interaction is needed for this knowledge to be transmitted) and both of them must be contemplated in the creation process. The transformation will occur by means of four modes.

- Socialisation: Tacit knowledge is transformed into new tacit knowledge.
- Externalization: Tacit knowledge is externalized and becomes explicit knowledge.
- Combination: Explicit knowledge results in new explicit knowledge.
- Internalization: Users integrate explicit knowledge into their routines and thus it becomes tacit knowledge.

New knowledge may be categorized as either additive, complementary or substitutive. The substitution of old knowledge with different new knowledge is a process of discontinuous learning, a process of learning to do better things as opposed to learning to do things better (Hall & Andriani 2002).

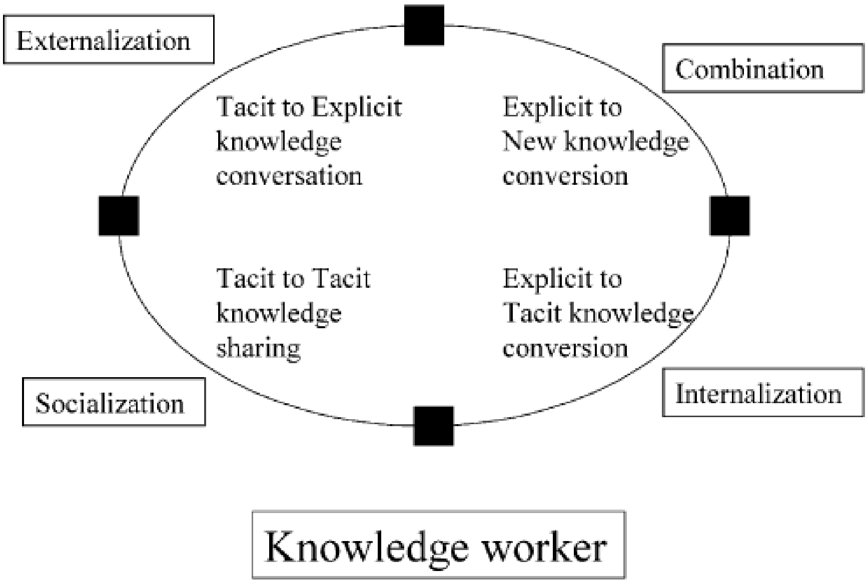


Figure 2-4: Knowledge spiral – Acquisition phase (Nonaka & Takeuchi, 1995)

The second stage represents the ***documentation phase***. "In this phase knowledge is captured, documented, stored and prepared for its transfer and its subsequent reuse." (Schacht & Maedche 2016).

The third stage deals with ***knowledge transfer***. The complex connections between knowledge source and target need to be analyzed. The principal activities of this stage comprehend recognizing the reuse needs, supporting the distribution processes and facilitating the knowledge development.

Stage number four is the ***reuse phase***. It is understood as the first usage of the transferred knowledge. Individuals have to first know what they are looking for, be able to select the proper knowledge and finally apply it.

The last phase includes all activities related to ***knowledge protection***. This fifth stage is often forgotten and some authors do not even consider it as a part of the knowledge management process. As we will see in the following chapters, keeping the knowledge actualized and knowing what kind of information is to be found in a base is of prior importance and therefore a phase for these purposes is required.

For the proper development of the whole process, IT can provide support regarding two basic knowledge management approaches. These are called codification and personalization. With the codification approach, more explicit and structured knowledge is codified and stored in knowledge bases (electronic knowledge repositories); contrarily, with the personalization approach more tacit and unstructured knowledge is shared through personal communication. In this case the role of IT is to help people to locate each other and facilitate communication (Kankanhalli et al. 2003). The implementation of both approaches is fundamental in any company, as no single solution can cover the knowledge management needs of an entire organization and the two views are not mutually exclusive. Nevertheless, the type of design activities occurring in a company and its competitive strategy shape the knowledge management approaches adopting. Generally companies selling standardized and well known products, where pieces are dependent one from another and automatization routines are desirable, the trend is to adopt codification strategies (often related to big organizations). On the other hand, when innovation is desired or the design of highly customized products is required, these activities should not or can not be automatized, as the product is not that well understood. Thus, these companies (often start-ups) tend to adopt personalization strategies (McMahon et al. 2004).

By means of these five phases, the objective of knowledge management processes should be achieved. That is "providing the right information to the right people at the right time, helping people to create knowledge and share and act upon information in ways that will measurably improve the performance of an organization and its partners" (Du & Liu 2011). Still, the current knowledge management level is way below its expectations. Some researchers have realized that even when having a clear system structure, there are some phases of the model that tend to be overlooked or even neglected. Moreover, knowledge is often treated in incomplete manner, allowing knowledge loss throughout the product life cycle (Sainter et al. 2000).

2.1.3 Knowledge reuse in engineering design

One of the most forgotten phases of researchers is knowledge reuse. It is often neglected, as it is commonly assumed, that once a document or piece of knowledge is found, its reuse is almost implicit (Schacht & Maedche 2016). On the other hand it is not easy to evaluate, how determinant the reuse of a given knowledge during a project was; furthermore its contribution to the project success cannot be measured. In several industries only the factors that directly contribute to an increase of the company's income get to be studied and paid attention.

Regarding the engineering design field, knowledge reuse aims to reutilize previous designs, artefacts or components, as well as the knowledge and expertise ingrained in them. It also refers to a sharing dimension, in the sense that knowledge can be unexpectedly applicable for solutions that at the beginning might not have been contemplated. Always with the practical motivation behind, that the capture and reuse of knowledge is less costly than its recreation (Fruchter & Demian 2002).

Knowledge reuse happens to occur both internally and externally to the person. Internal reuse relays on personal memories and own experiences acting as knowledge repository. On the contrary, external reuse occurs when the knowledge comes from an external source (Fruchter & Demian 2002).

An interesting fact is that while internal reuse is mostly successful, external reuse is not. Internal reuse relies on the most perfect knowledge base, the humans' brain; where knowledge acquisition, documentation and transformation happens automatically in the most instinctive way. Researchers have found out, that designers can quickly find reusable items in their memory, furthermore they remember the context of each item and understand the whole, allowing a more effective reuse (Fruchter & Demian 2002).

Contrarily, when trying to reuse external knowledge we face the following problems. First of all, designers might not appreciate the importance of documenting their discoveries and therefore they don't do so; sometimes they don't even realize that they are coming up with solutions that might not be so obvious for other designers. Documentation is also often limited to formal knowledge and the reasoning or context behind the decisions taken is missing. Moreover the lack of mechanisms for capturing, finding and retrieving reusable knowledge play also an important role (Fruchter & Demian 2002).

Thus it can be deduced that the reuse problem has three main origins. One regarding the understanding of the context and solution applied, another regarding the content of the knowledge being documented and the last one concerning the whole knowledge base system or software used to support it.

Table 2-1: Problems of knowledge reuse

Nr.	Problem	Sources
1	Context understanding	Majchrzak et al. (2012), Fernández Miguel et al. (2016)
2	Content documentation	Kuffner and Ullman (1991), Cross & Sivaloganathan (2007)
3	IT support/Knowledge base	Musen (1991), Liebowitz (2001), Hoeschl & Barcellos (2006)

The first statement is supported by some authors like Garud and Kumaraswamy, 2005 or Postrel 2002, who pointed out that knowledge reuse, is based on a prior phase called knowledge integration. An immediate process between knowledge capture and knowledge reuse. This phase implies a fully understanding of the topic treated. That is, knowledge might be documented and transmitted, but without its understanding, there is no possibility that it can be reused and successfully applied (Majchrzak et al. 2012), (Fernández Miguel et al. 2016).

Figure 2-5: Knowledge Integration

The second cause of knowledge not being reused is very complex and project dependent. Kuffner and Ullman (1991) found that mechanical engineers usually request information concerning the operation or purpose of a designed object, information that is not typically captured in standard design documents: drawings and specifications.
It is important to keep in mind, that the goal of design reuse is to utilize past proved designs in new situations, so that chances of success are increased; producing designs with known performance that are cost-effective to manufacture (Cross & Sivaloganathan 2007). Helping designers to achieve this goal is what will provide them with an added value and therefore in their necessities is the key to select which content should be documented and which one represents only a waste of time.

One proposition is the one of Kuffner and Ullman (1991), who point out that a knowledge base for engineering design should first of all help finding reusable items, secondly provide the project context and lastly provide the evolution history of the product. The second and third requirements are meant to allow the understanding of the solution and assessing its reusability.

Last but not least, let's approach the third reason frustrating knowledge reuse. When we speak about sharing and reusing knowledge, at first glance there is an underlying presumption that knowledge is a commodity that can be replicated and moved from place to place; a substance that can be acquired from human experts and transferred from one computer system or program to another. But, how can one propose to share or reuse something that does not have properties such as locality and persistence? (Musen 1991).

Philosophers and researchers have dealt with this question for years. It is scientist and psychologist Allen Newell who has most compellingly attempted to define knowledge for the benefit of workers in artificial intelligence (AI), so to say, in terms of its reuse and future application. Newell views knowledge as an abstraction that cannot be written down and that can never be in hand. Knowledge is for him, that which an observer would explain to an intelligent agent (human/machine), that allows the agent to model his behavior rationally to achieve some perceived goals, according to what learnt from the observer (Musen 1991).

Knowledge is thus seen as a capacity to react in a given way and not a material substance. Not even the data used to represent knowledge can be considered as such, the rules, symbols and frames can not generate intelligent behaviors per se (Musen 1991).

Knowledge reuse is a very complex process that involves many dimensions, including the reapplication of lexicons, ontologies, inference syntax, tasks, and problem-solving methods. Principal obstacles to all current work in knowledge sharing involve the difficulties of achieving consensus regarding what knowledge representations mean, of enumerating the context features and background knowledge required to ascribe meaning to a particular knowledge representation, and of describing knowledge independent of specific interpreters or inference engines (Musen 1991).

Artificial Intelligence (AI) is introducing herself as the solution that will eliminate the gaps and inconsistencies of the current knowledge management systems. Nevertheless there is still a lot of work to be done in this field (Liebowitz 2001), (Hoeschl & Barcellos 2006).

2.1.4 Challenges and perspectives of knowledge reuse

Considering the importance given to knowledge in the current business environments, plus the several studies carried out about the topic, why is that only a 20% of the intellectual assets of a company are captured and reused? In fact upward 80% of design is adaptive or variant (Pahl & Beitz, 1996), which does not require the inventive aspects of creativity, resulting in a process that is particularly reliant on information and knowledge. Knowing that, why are not design methodologies taking advantage of this situation?

To address these issues, the first question to be asked is whether knowledge or rather, the right knowledge is being documented. This issue has already been introduced in the last chapter. Designers claim that the current systems are not broad enough to provide a proper knowledge reuse. They ask for methods, that not only gather geometrical data or bureaucratic forms, but that also provide context and explanation behind the decisions taken in a given design. According to Marsh (1997), knowledge consists of the assimilation of related information addressed in the context of a frame of reference. Is this context we are talking about, the one that is often missing, and the one that makes the connections between different information's and their posterior reuse possible. Researchers are also aware of this issue. Knowledge is difficult to be expressed as ''know-how" (procedural or heuristic knowledge) and especially as ''know-why'' (e.g. experiences, insights into cause–effect relationships). Nevertheless, these tacit components are crucial for answering pressing project questions or problems, that numerical data are not able to solve (Williams et al. 2001).

Tacit knowledge is composed of experiences. These are by definition bounded to people who are involved in the problem solving process, but who many times are not in its documentation. If during the process these practices are not shared, the learnings will not be transferred and consequently lost. Thus, the end of a project is considered to be the beginning of the organizational amnesia (Weber et al. 2001).

Several authors argue that the fundamental problem of organizational learning in connection with the project work can be found in the conflicting aims between a project and the surrounding organization. While the existence of an organization is designed for the long run, a project exists only for the duration of its completion. To overcome this conflict is necessary to do an extra effort; starting from the head company members. Documentation and learnings collection do not take place systematically and therefore constructing a knowledge sharing culture and providing with the right tools to do so, is of vital importance.

The four main elements that play a role against knowledge documentation are time, motivation, discipline and skills (Schindler & Eppler 2003).

- ***Time***. Time pressure towards the project end and the new tasks already assigned (people leaving the project before it ends) rarely leave employees time to document their know-how. Moreover, the integration of experience recording during the project seldom occurs.
- ***Motivation***. Insufficient willingness to learn from mistakes (fear of being punished) and lack of reward systems that promotes sharing and documenting.
- ***Discipline***. Employees do not see the personal use of coding experiences and prefer to keep the knowledge for themselves being so "more valuable" for the company.
- ***Skills***. Lacking knowledge debriefing methods or underestimating the process complexity can cause a poor documentation that might not be reusable in a future.

Relating the last bullet point, the authors of the paper "Sharing engineering design knowledge in a distributed environment" (Zdrahal et al. 2000) also remark the importance of having designers possessing the skills that allow them to work effectively in the current design environment. They describe the design activity as an increasingly distributed and collaborative discipline, where learning from experiences play a decisive role and therefore being able to analyse different solutions from different past cases and assess their relevance to be reused, becomes a vital skill.

Researchers Chou et al. (2007) bring on the table the organization information progressing (OIP) capabilities of a company. They argue that understanding and studying these capabilities will report a better performance of the knowledge management activities and consequently of the knowledge reuse. For them the organization is seen as a learning system resulting in the accumulation of knowledge. For this system to work effectively, employees have to actively become part of the knowledge management activities. In their paper it is suggested, that the driver for employees to do so, is their perceived utility of the mentioned tasks. The results showed that an increase of codificability (knowledge codification into standardized formats that facilitate its transfer) is likely to lead to a higher perception by the employees' of the usability. This combined with the teachability (easiness of communication and distribution of a given knowledge) enhances the organization's memory capability. So will the knowledge integration process be successfully supported and the knowledge dissemination within the company boarders will be more effective, allowing this way a posterior efficient knowledge reuse.

On the assumption that all the above were accomplished, the IT support problem is still to be faced. (Recall chapter 2.1.3). The aim of current knowledge bases is to facilitate knowledge sharing a reuse. In chapter 2.1.3 it was explained, that for knowledge to be represented, a great amount of factors have to be considered. Terminologies, ontologies, and problem solving methods are a couple of them. The challenge is then, to be able to share the knowledge contained in different knowledge bases, being all these just mentioned factors disparate from one base to another. The incompatibility among systems and formats, make impossible bringing two knowledge bases together. Four main impediments are responsible of this (Neches et al. 1991).

1. ***Heterogeneous representations.*** There are several approaches to knowledge representation but one representation formalism can not directly be incorporated into another. Unluckily there is no universal representation formalism that perfectly fits all problems and therefore knowledge sharing involves translating the content of one base to the other. Process that has to be done manually, as nowadays there is no tool able to commit this task.
2. ***Dialects within languages families.*** Sharing knowledge across systems can be very difficult if the knowledge has been encoded in different dialects. This might completely change the meaning of the message or completely leave its interpretation to the understanding of the specialist involved.
3. ***Lack of communication conventions.*** To share the knowledge of two or more different bases does not mean requiring a merger between them. Separate systems could communicate with one another and so benefit from each other's knowledge without sharing a common base. (A rule could be inferred from the knowledge of one base to the one of another). Nevertheless, this is normally not possible, as we lack an agreed protocol that allows systems to interact and to query each other.
4. ***Model mismatches at the knowledge level.*** In case all previous impediments were resolved, terminology issues would also act as a barrier for the effective communication between different bases. Lacking a shared vocabulary will imply a failure when trying to correlate the knowledge from one base to the other. (Sources and targets are called different in the two bases, avoiding so the automatic linkage). (Neches et al. 1991)

Thus reusing or sharing the knowledge contained in different bases with the systems that we currently know and use is a very tough task. Nomenclatures, ontologies and even the inferential associations from one design problem to a given solution vary between bases, requiring a previous study of every base before trying to benefit from its content. Nonetheless, the purpose of researchers in not finding a universal language that solves this situation, but to create standard interchange formats, from which the same knowledge could be translated into a variety of symbol-level representations. This would allow interconverting knowledge into particular representations according to the concrete base's system and format (Musen 1991).

2.1.5 Types of knowledge

To be able to approach the knowledge reuse questions, first we need to know, which types of knowledge exist and which of them are actually required when carrying an engineering design project. This last point is a very important issue to take into account, as the literature indicates that the main obstacle to knowledge reuse is matching the resolution which the knowledge is captured and stored and the resolution at which it is required in the new design.

Let's first start with the meaning of Design Knowledge. Several authors have discussed about this term. A good definition according to the purpose of this thesis is the one of Van Aken (2005) who understands the topic as "knowledge that can be used to produce designs". What this knowledge needed to produce designs is, is a controversial question that many researchers have addressed. Nevertheless as design projects are very product-related, is not easy to come with an answer to determine general types of knowledge.

In chapter 2.1.3 we saw the proposition of Kuffner and Ullman (1991) about the knowledge that should be contained in a base to provide value to the end-users. Nonetheless, some authors start by defining, which purposes this knowledge should accomplish. Du & Liu (2011) state that this knowledge is meant to support the design process, by being shared between all product developers having an impact on the final product; moreover it should be relevant to be transmitted among projects and so support the knowledge reuse. Other authors like Ishino & Jin (2002) address the problems that design engineers have to face. They claim that understanding their troubles is the first step to be able to provide them with the most suitable knowledge and so facilitate their work. Three problem characteristics are to be recognized:

- A design task is made up of multiple activities.
- Each of these activities, depend on one another.
- The alternatives of products are based on various requirements.

Simultaneously other studies, answer the knowledge question by focusing on the design process phases and so try to identify which knowledge should be at which phase and with which purpose provided. Erden (2011) identifies six design phases in his work.

1. Problem definition
2. Conceptual design
3. Preliminary design
4. Detailed design
5. Design communication
6. Final design (Fabrication, specifications and documentation)

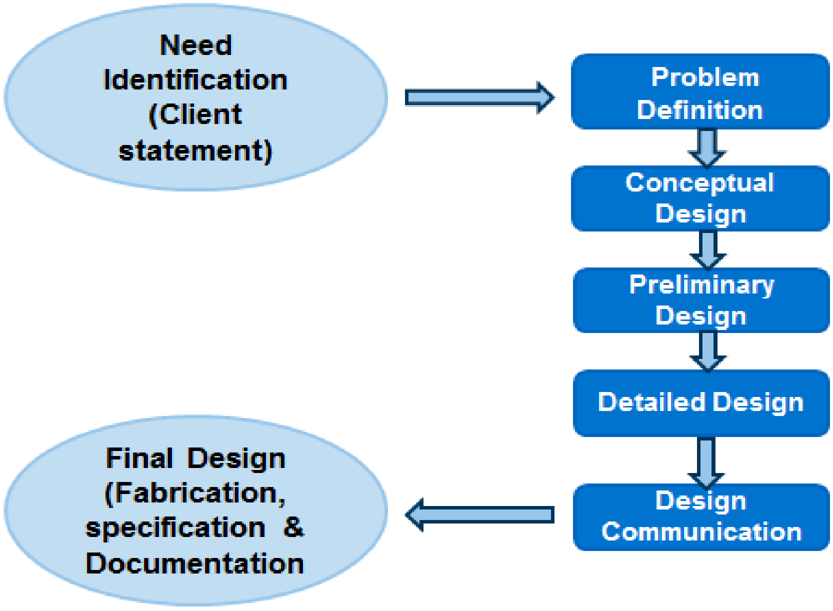


Figure 2-6: Design process phases (Erden 2011)

A different formulation of the knowledge that a designer's base should contain is the one of Hubka 1996. He claims that design can be considered to be an information process or an information transformation process. The various design states contain different extents of information; however, the process of transformation from one information state to another is the result of a decision process, driven by knowledge and information. Is this reasoning behind the decisions, the knowledge that allows designers to jump from one design to the next one; and therefore is also the knowledge that future designers should receive when exploring a given solution.

An also very interesting study is the one of (Hicks et al. 2002). These authors propose four different types of knowledge according to four types of reuse purposes. These are: decision making, descriptive elements, measurement and distribution.

- Decision making, describes previous decision processes. (Decision outcome, alternatives and basis of the decisions).
- Descriptive elements describe and classify objects and processes.
- Measurement represents the value of particular aspects of an object or process.
- Distribution can include all the categories above and is meant for the exchange between people, environment or processes. (Mostly formal and standardized knowledge).

These authors explain in their study that the purpose, for which the knowledge is required, is closely related to the situations or project stages where it is going to be applied. Implying this most of the times, its application in new situations that may or may not be familiar. Consequently, the authors propose four states of applicability, related to four correspondent levels of knowledge.

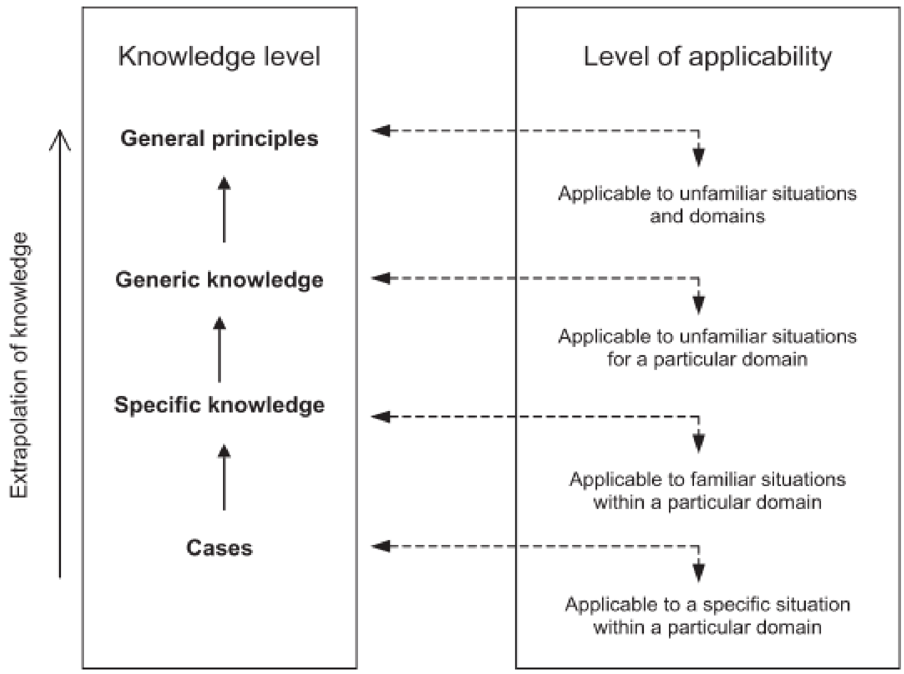


Figure 2-7: Knowledge levels and states of applicability (Hicks et al. 2002)

From all these approaches different knowledge classifications and requirements are to be obtained. Evaluating the validity of their discoveries is not the prior aim of this thesis and therefore, I will present the results obtained by one of the students of mi tutor who devoted her thesis to broadly classify the engineering design knowledge (Carro Saavedra et al. 2016).

Taking as starting point the classification of knowledge in an organization made by Cristina Carro Saavedra, and digging into the literature of the engineering design field, Serrano (2016) came up with a taxonomy representing all the types of knowledge needed in design engineering (Figure 2-8). Her aim was to propose a unique classification of types of knowledge for the field, as numerous classifications exist but they are usually redundant or incomplete. The classification is meant to give a clear overview of the knowledge needed in the design phases of a product.

To do so, Serrano (2016) defines five knowledge dimensions that cover all the knowledge requisites found in her research. By dimensions are understood the degrees of freedom in which knowledge can be described. Here a brief description of each with their corresponding categories.

- Origin: Provenance of knowledge in the firm. Categories: Internal or external.
- Nature: The essence of knowledge (meaning the way that it can be articulated, captured and shared). Categories: Explicit, implicit, and tacit.
- Concretization level: Level of detail of knowledge. Categories: General or specific.
- Situation of knowledge acquisition: Situations of knowledge acquisition refer to which activity the knowledge is obtained from. Categories: Experience, contact, and human.

- Subject: Field of study of the knowledge. Categories: Product knowledge, process knowledge, supplier of knowledge or knowledge about the environment.

During the development of this new taxonomy it was proved that authors in literature are naming types of knowledge differently, even though they mean the same thing. Moreover targeting the design engineering field made Serrano (2016) eliminate a couple of the dimensions considered in previous knowledge classification models; nevertheless her classification encompasses every kind of possible knowledge being used in engineering design projects, without redundancies and in a very specified way. Consequently, the taxonomy will allow both: To classify single pieces of knowledge and to be used as a tool for engineers when facing new designs (guideline of types of knowledge existent to accomplish different design tasks).

This classification will always be kept in mind in the development of the project, so as to consider every kind of knowledge being generated during the MyMINI Project and its posterior representation in the implementation of the knowledge base.

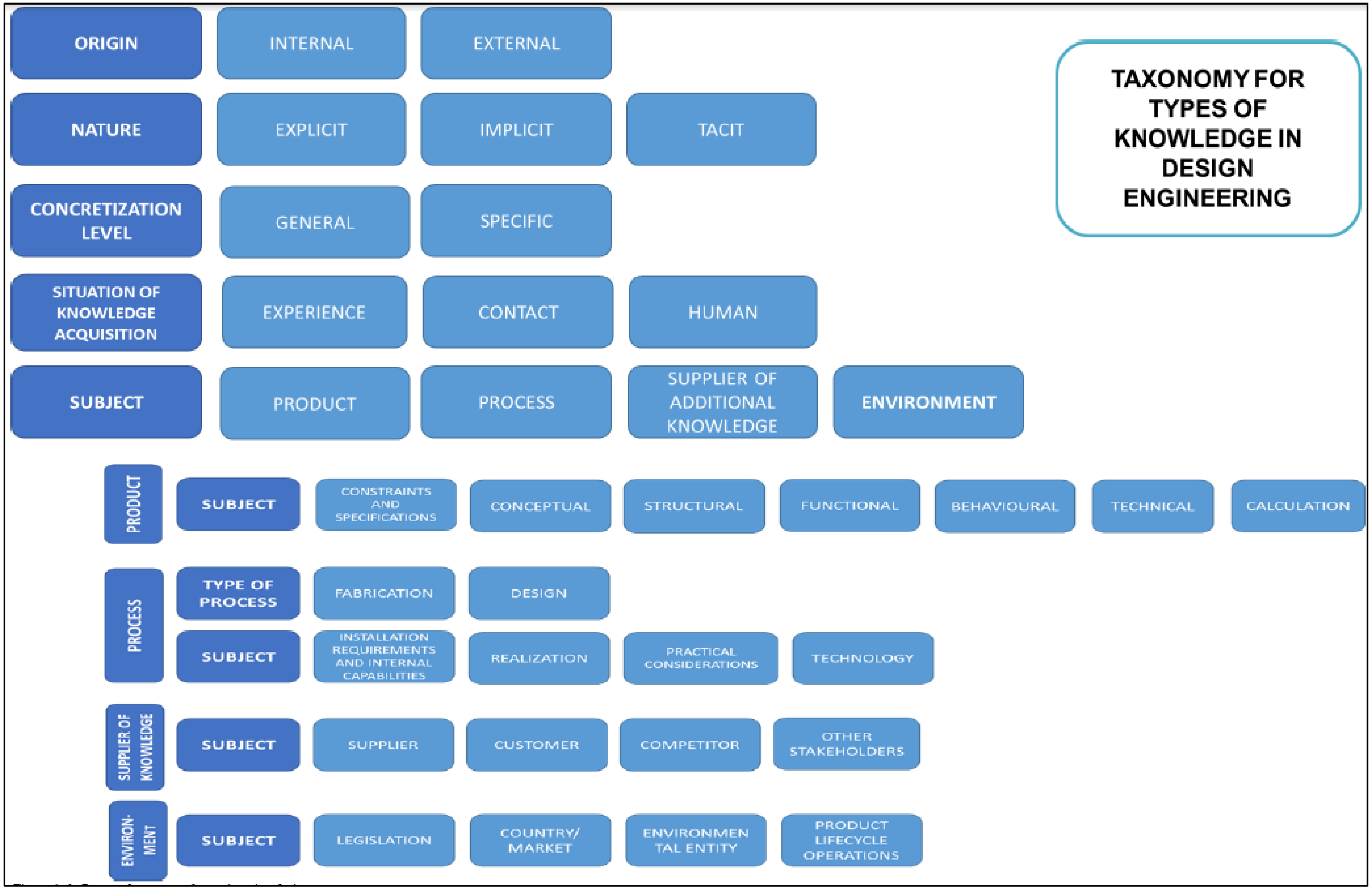


Figure 2-8: Types of knowledge - classification. (Serrano 2016)

2.2 Definition of knowledge base

A knowledge base is generally understood as being a centralized repository for information and a resource for the dissemination of knowledge. Milton (2007) expresses it as "a field or group of fields that holds knowledge representing the expertise of a particular domain". In the coming chapters we will go into detail explaining what the purposes, requirements and challenges of knowledge bases are and how to create them, among others.

2.2.1 Purpose of a knowledge base

Nowadays the major goal of companies all over the world is to continually optimize their product development processes and go a step ahead their competitors, with improved cost efficiency on the market. This increasing competitive pressure plus the rising demand for individual solutions creates a permanent need for innovation (Whitney et al. 1999, p 2), (Schäfer 2006, p 6). The individualization trend, broadens the range of products and their complexity, so do their processes to adapt to them. This can be translated into more and more data (with its inconsistencies and information gaps) to be managed with the correspondingly increase in communication effort (Schäppi et al. 2005, p 422), (Schäfer 2006, p 35). The whole product development process has become very specialized and the amount of information and knowledge is no more barely manageable without the help of machines.

The goal of a knowledge base is then to provide the decision maker with an intelligent analysis platform that enhances all phases of the knowledge management process (Nemati et al. 2002). Being able this way to provide the right information, at the right time, in the needed quantity and quality, in the place where it is required (krcmar 2005). The end purpose of the knowledge base is then to make the search more time and output efficient, and so allow developers to spend their time in creative activities, avoiding unnecessary iterations in the development process (Lauer 2010).

2.2.2 Current knowledge bases and their limitations.

Going back to the origins of knowledge bases, traditionally design rationale systems were used for three reasons: (1) argumentation, (2) communication, and (3) documentation. Designers used to access information to validate their decisions and justify the designs. Thus, to support the retrieval of knowledge from a system, indexing methods have been over years applied. (Ahmed 2005).

The most classical concept of a base understands it as a selection of one or more data to be documented, creating at least one document. This one document acts as a memory, containing in any way knowledge about a given topic that would be in some way represented. The documents are then indexed by creating an index outside the base which associates the keywords characterizing the documents with the item location. The keywords are meant to be comprehensive and accurate. Indexing may be accomplished by providing to a keyword search engine indexing agent both the textual representation of each selected item's data and the selected item's location identifier. The indexing agent produces an index that associates keywords with resource locators, and each resource locator includes a textual representation of a data item location identifier.

The typical researching methodologies in which this base conception relies are the following:

- Keyword: A "keyword" search is a pattern-matching search which tries to locate instances of digital data using a key word or phrase. Many conventional Web search engines support keyword searches.
- Browsing: One alternative to keyword searching is "browsing" through the available data until values of interest are located (according to the numbers or letters tipped by the user). An important difference between keyword searching and browsing is that keyword searches focus much more quickly on portions of the data that are likely to be of interest. This is particularly true if the keyword search is performed on data that is grouped by subject matter.
- Query: An important difference between query searches and keyword searches is that query searches normally presume the existence of relations or other structures in the data and contain assumptions about that structure. In other words, query searches are governed by strict syntax rules as command languages with keywords or positional parameters.
  (Bowen & Brown 2000).

Over the last decades, technology and engineering design itself have disproportionately evolved, becoming the design activity a collaborative work between multidisciplinary teams. As the cooperative activities in engineering design increase, so does the need for computational frameworks of knowledge representation. The current knowledge bases have then developed into intelligent repositories, design artefact modelling systems to facilitate the representation, capture, sharing and reuse of corporate design knowledge (Szykman et al. 2000). This migration from traditional design databases to design repositories is due to the fact that design repositories (knowledge bases) try to capture a more complete design representation that goes beyond the narrow representation of past databases (CAD models or drawings) by involving the categorisation of product functions, behaviours and design rules. Nevertheless, not every aspect of a design is usually covered (Firdaus et al. 2015).

Already the current knowledge bases are working in the facts above mentioned. As an example of this, we can name the knowledge base proposition of Firdaus et al. 2015. They realized that the content of most bases was mainly limited to formal documents. Consequently, a great amount of contextual, informal and inductive reasoning behind the decisions taken was getting lost. Thus it became clear for them, that multimedia files had a big potential to improve the recording of informal information for reuse at later instances.

Being aware that the capture of information being done easily and unobtrusively is "the key to the construction of a comprehensive project memory" (Conway and Ion, 2013, p. 146); Firdaus et al. 2015 created a system based on two basic workspaces: an engineering design workspace, for engineers to work on new designs; and a documentary workspace, for the activity that is being done to be recorded and so to serve as a knowledge source for other engineers. In his work, a query search is present (driven by meta-keywords). Nonetheless, this is not the only search mechanism that the system includes. Pictures, tittles and additional information can also act as a searching tool. This user-centred knowledge management system, aims to provide a friendly interface and allow designers to document their findings while working in their regular design activities. It is created to encourage the use of multimedia files and to integrate formal and informal knowledge about the projects. Moreover this system connects information about the author of a document (studies, years of experience, area of specialty, etc.) with the mentioned document, so that the source of a given knowledge can always be found.

Figures 2-9 and 2-10 show a couple of screenshots of this knowledge repository, so that the concept of knowledge base can be better understood.

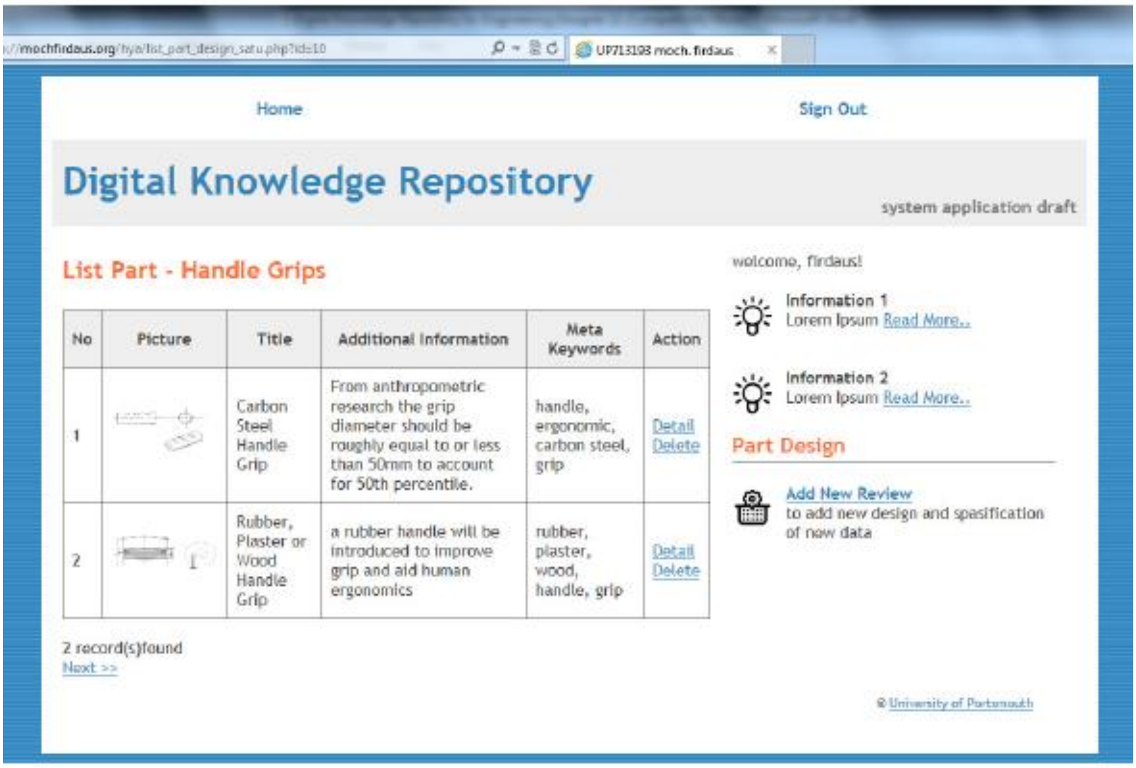


Figure 2-9: Screenshot of the list of search results (Firdaus et al. 2015)

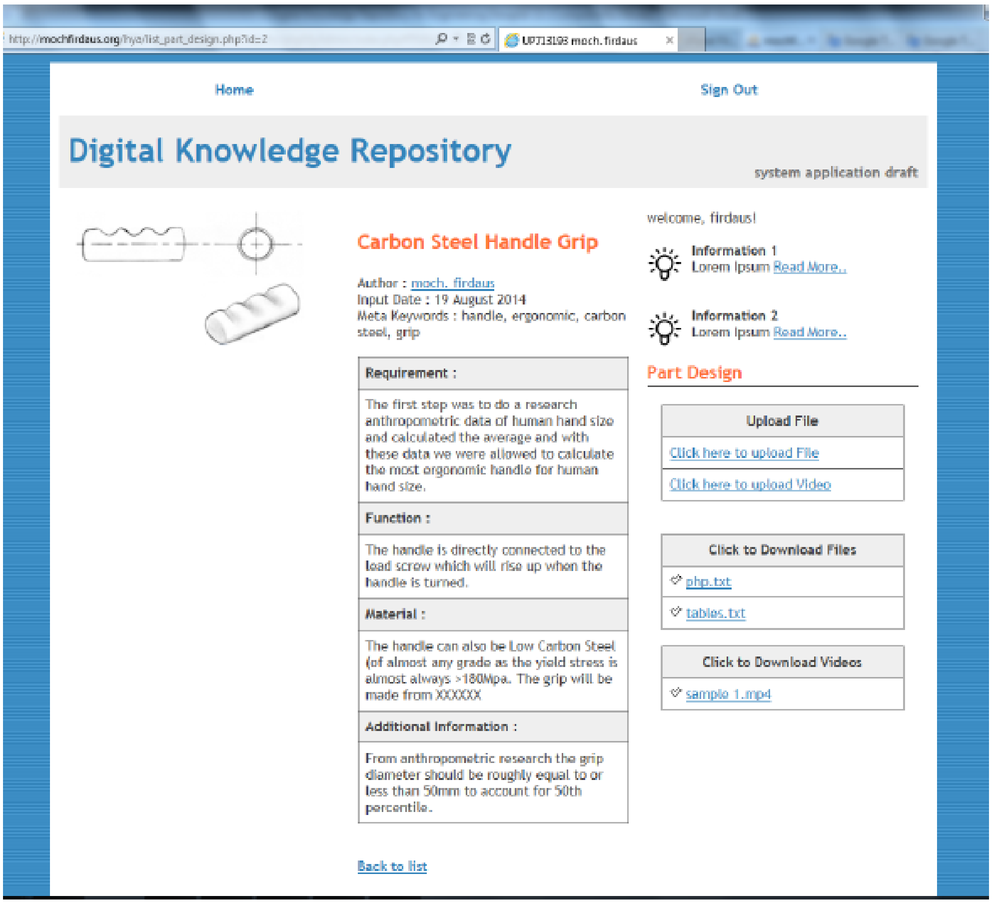


Figure 2-10: Screenshot of the detail design interface (Firdaus et al. 2015)

How can we affirm that current knowledge bases have limitations, i.e. they are not performing the way we would like them to? Two clear figures reveal this fact: engineers spend approximately 40-66% of their time searching and selecting information (Li et al. 2004); and only 20% of the intellectual issues of a company get to be documented and reused (Cross & Sivaloganathan 2007). These two figures are not exclusively related or caused by a poor performance of the knowledge bases but they do show that there is room for improvement also in this aspect. The simple knowledge repositories are no more helpful in the complex knowledge networks of the projects of today, where engineers have to invest their working hours searching from the plurality, not being able to evaluate the results into detail to obtain the relevant knowledge.

Another issue that current bases are not able to approach is that users can't often specify exactly what information they lack (Ahmed et al. 2004, p 162). The essential difference between the information needs and the demand is that the user's own needs are not always exactly known and, therefore, the information found might not fit the expectations. This not only induces devoting more time in the search but also a frustration feeling.

However; an influencing factor in the perceived efficacy of a knowledge base, is that only a fraction of the required knowledge exists on computers; the vast majority of a firm's intellectual assets exist as knowledge in the minds of its employees. Hence, a data warehouse does not necessarily provide adequate support for knowledge intensive queries in an organization. What is needed is a new generation of knowledge enabled systems that provide the infrastructure required to capture, enhance, store, organize, leverage, analyze, and disseminate not only data and information but also knowledge (Nemati et al. 2002). This is also known as strategic vulnerability of a company. If the ratio of tacit knowledge to total knowledge is high, the position of the company is Externally Safe because the knowledge is difficult to identify and copy; but it is Internally Vulnerable because employees may leave and take their personal knowledge with them **(**Hall & Andriani 2002).

In summary, it can be said that the information provided is often inadequate and wrong targeted. Nowadays the vision of providing the users with the right information at the right time, to the right people, is only partly available (Lauer 2010).

As mentioned in previous chapters, the increasing pressure in achieving competitive advantage, a better cost-efficiency performance and the reduction in the time to deliver are encouraging the development of new possibilities that could solve the actual limitations.

A good example of steps being made in the right direction is the new web conception called Web 2.0. Some insight can be gained from this concept to be implemented in future knowledge bases. Web 2.0 is a combination of ideology and technology. Some of its outstanding features are the user-centred orientation, the initiative information release and acquisition, self-organization of information and management, plus low cost on information utilization and sharing. Its aim is to excavate enterprise staffs´ tacit knowledge and well integrate internal and external information resources of the enterprise, making up the insufficiency of traditional knowledge portals. (Wang et al. 2008).

Another promising field where all eyes are fixed on is artificial intelligence. This means making knowledge bases become "intelligent", so that they can learn from past situations and pasts designs, in order to provide with relevant knowledge the present designer. This is a very complex and innovative field that is still developing and therefore escapes the scope of this work (Liebowitz 2001), (Hoeschl & Barcellos 2006).

2.2.3 Requirements and challenges of knowledge bases

For a profound understanding of what a knowledge base is and what we can expect from it, is indispensable to comment the following two topics. Which are the requirements that a knowledge base aim to fulfil and which problems do knowledge bases face in terms of its development and posterior use.

By now we have already seen what an important role knowledge bases play in knowledge management and the great impact that having and properly using a knowledge base can have in companies' performance. Important is tough to consider, that when talking about the requirements of the base to achieve these positive impacts, we have to think of both the knowledge seeker and of the knowledge documenter. To picture it simple, a knowledge base has two main information flows; the one providing the information and the one extracting or using it.

Figure 2-11: Information flows in knowledge bases

The authors Nemati et al. (2002) developed their study attending to what they considered the three fundamental requirements of every knowledge base.

1. Ability to efficiently generate, store, retrieve and manage explicit knowledge in various forms.
2. Ability to store, execute and manage the knowledge with minimal interaction and cognitive requirements from the decision maker.
3. Ability to be updated and actualized.

Milton (2007) adds to the previous mentioned, some more requirements. He points out the importance of creating a base for as many end-users as possible. Always thinking about their knowledge needs an expectation from the base. It is important to assess the contributions of every end-user sector, so as to get different impressions and be able to fit their necessities. That leads to the next requisite. A knowledge base has to provide the user with valuable knowledge, being this complete and concise. Milton 2007 also makes an appointment about the usefulness by stating, that a clear structure should support the base, so that both documenting and searching could be easily done; furthermore, that it can be reused.

Other researchers state that offering the possibility to visualize the base structures in different ways, by means of different representations might be helpful for finding the right information and getting to better understand the base operation. Knowledge must not only be reachable thanks to filtering tools (text) but it should also be seen (where it does come from, with which other documents is to be related etc.). Moreover this can satisfy the need of different end-users who approach the search from diverse points of view. This becomes very helpful when regarding aspects as teachability and the incorporation of new designers to a company (Chou et al. 2007).

Nevertheless is the contribution of Lauer (2010) with his doctoral thesis the one that will strongly frame the requirements of the knowledge base to be implemented during this work. He works on the basis of two hypotheses that are:

1. “If a general and intuitive description of parameters for processes and documents is defined, then it is possible to draw automatic conclusions about their relevance.”
2. “When processes and documents are automatically connected, the end-user experiences tangible benefits.”
   (Translations of Lauer’s (2010) work)

Unfortunately his work goes beyond the one of this thesis, as he attempts to create a dynamical base. Still we can simplify his hypothesis for our own purposes. The first hypothesis means, that having the same descriptive parameters for document and processes, help to structure the knowledge of a system in an analogue manner, allowing connections between documents and processes to happen. These parameters should be understood by every user. As corollary from the first assumption, we induce the reformulation of the second one. If this connection happens, users can relate their document with the project processes and the other way around, hence added value is appreciated.

In light of the above, the following eight requirements rose.

- ***Adjusted to demand.*** A requirement for the base is to provide the right knowledge in terms of amount and relevancy according to the situation; not overburdening the user with information that is not meaningful for him/her.
- ***Process oriented.*** As mentioned before, having a connection between processes and documents facilitates the documentation and the search of information, and it is a very valuable factor in knowledge reuse, as it allows a new researcher to better understand the context of the knowledge.
- ***Across phases.*** The knowledge base should contain documents of the whole process. From the very beginning until the very end. Otherwise it would lead to knowledge gaps.
- ***Across levels.*** Along almost every project in design engineering, products or even documents can be broken down into pieces, so that it is possible to specify the content of each. A knowledge base should be able to represent the knowledge through every level of complexity and abstraction, showing the whole picture of the contained knowledge. This is particularly important to understand and justify the decisions taken, not losing the track of the development.
- ***Different perspectives.*** When developing a knowledge base is determinant to count on different people coming from different areas or sectors. They might have different points of view of how to access the information, plus different needs when regarding the content required. That's why the base should provide different ways to access the information, so that it can be found from different perspectives. Despite the different views, the system must be kept simple and its application intuitive, not forgetting the low-maintenance cost of the method.
- ***Added value must be perceptible.*** The intuitive terms should bring on the acceptance of the method and so the added value of the method recognised.
- ***The search function must be supported.*** The search function must be digitalized, in a way that just by giving certain parameters; the software could find by itself the knowledge behind them.

Table 2-2: The eight knowledge base requirements (Translation of Lauer 2010)

Requirements	Description
1. Adjusted to demand	What is needed?
2. Process oriented	When is it needed?
3. Across phases	Processphase-specific
4. Across levels	Information from various levels of abstraction to be visualized together
5. Different perspectives	Enable filtering by different perspectives (e.g. Phase view, Product view, etc.)
6. Simple application	Greater acceptance in the use
7. Added value must be perceptible	Greater acceptance in the use
8.The search function must be supported	The description parameters are also used as search algorithms

All these authors empathize the need of speeding the decision making process. They rely on the simplicity and inductivity of the base, supported by the use of strong structures and unmistakable terminologies that truly represent the project from every different perspective and abstraction level.

Not only should the pure functional requirements be fulfilled in order to make a knowledge base work, but also some other factors. It is time to consider the so called critical success factors. In the paper *Critical success factors for implementing knowledge management in small and medium Enterprises* (Kuan 2005), six factors are considered. These factors are translated into six critical areas to be worked, in order for a knowledge base to be effectively used. A strong knowledge management strategy must be present (1); this should be supported by CEO´s high commanders and a knowledge management infrastructure (“lead by example”) (2). The knowledge base should be the result of a solid ontology and knowledge structuration (3), sustained by the suitable tools and software systems (4). Lastly the company needs to have a supportive culture (5) that measures and incentives knowledge sharing (6). Put in other words, six areas named knowledge strategy, leadership, culture, structure, IT and measurement (Liebowitz 1999).

Those areas should lead with aspects like providing the designers with enough time to documents their findings, promote the knowledge share (eliminate the fear that if I write down what I know, I won't be valuable for the company anymore); give the users proper guidelines to document and search, being the company leaders the ones leading by example when it comes to the use of the knowledge base; furthermore promoting its fully use caring of its update and maintenance.

Once the requirements and success factors are known, one might think it will be easy to run a suitable base for a given company and so facilitate the knowledge sharing. What we haven´t discuss until now is the challenges that creators face when designing a knowledge base.

Table 2-3: Requirements for knowledge bases and companies to encourage knowledge reuse

Nr.	Requirement	Source
1	Knowledge available in various forms	Nemati et al. 2002
2	Ability to operate the base with minimal interaction and cognitive requirements from the decision maker	Nemati et al. 2002
3	Ability to be updated and actualized	Nemati et al. 2002
4	Designed for as many end-users as possible	Milton 2007
5	The knowledge stored must be valuable. Complete and concise	Milton 2007
6	The knowledge base must be supported by a clear structure + Solid ontology	Milton 2007, Liebowitz 1999, Kuan 2005
7	Different structure visualizations & Knowledge representations	Chou et al. 2007
8	Adjusted to demand	Lauer 2010
9	Process oriented	Lauer 2010
10	Across phases	Lauer 2010
11	Across levels	Lauer 2010
12	Different perspectives	Lauer 2010
13	Simple application	Lauer 2010
14	Added value must be perceptible	Lauer 2010
15	The search function must be supported	Lauer 2010
16	Supportive knowledge management strategy	Liebowitz 1999, Kuan 2005
17	Supportive CEO's leading by example	Liebowitz 1999, Kuan 2005
18	Suitable IT tools to run the system	Liebowitz 1999, Kuan 2005
19	Supportive knowledge sharing culture	Liebowitz 1999, Kuan 2005
20	Knowledge reuse impact measurement - Incentives	Liebowitz 1999, Kuan 2005

One of the most relevant issues that face knowledge bases in engineering design is the changing dynamics of the development processes. Problem even more pronounced, when referring to the very initial phases of a product birth or when innovating. The uncertainty and imprecise information about how the product in the future will develop, harm finding an appropriate knowledge base to support the design activities. Moreover, knowledge base designers have to create a large number of knowledge elements. They should turn models and abstractions into individual elements with their own descriptions and definitions. It is also hard to anticipate all the details that it will be afterwards needed. Actually, even if the developers understand the domain very well, it is hard to picture how all the knowledge should be expressed correctly. As some part of the knowledge is represented, there will be many missing pieces that should be completed. It is hard for knowledge base developers to keep track of what pieces are still missing, and to take them into account as they are creating new elements.

Not only defining the pieces of knowledge represent a challenge for designers, but also to stablish the proper relations between them. The risk of having inconsistencies in such a big system between connections of newly defined elements becomes a reality (Kim & Gil 1999).

Once again, the last purpose of considering these requirements and challenges is no other than to reduce the searching times, making them more productive and efficient; leaving this way more time for devoting creative activities avoiding unnecessary iterations in the product development process.

2.2.4 Knowledge to create a Knowledge Base

One of the most challenging steps in order to generate a knowledge base is to be aware of all the information that is going to be stored in it, and how it should be structured and connected. This leads us to consider three types of knowledge that would help locating the mentioned knowledge: metadata, ontology, and mapping.

Metadata

Metadata means the data about the data. It provides users the information about the product data in order to help them locate the knowledge that they are interested in. Some examples of the information included in the metadata are the names, designers, major features of products, and the locations and data formats of the documents. For the users metadata serve as a map of product data. The metadata are the major part of the knowledge base, but there is no standardized content of the metadata because it is application specific. The first step of building a knowledge base is to determine this specific content.

It can be said, that metadata fulfils a double purpose. It condenses and codifies knowledge for its reuse, generating mutual relationships (connections) through the ontology (Yoo & Kim 2002).

Ontology

The ontology stablishes the meaning and relationship of the vocabulary used to improve the search capability in knowledge bases. It typically consists of definitions of concepts, relations and axioms. As it provides structured sets of terms for describing some domain, they can promote knowledge reuse and provide system builders with a higher-level platform.
Its main purpose is then to capture domain knowledge in a generic way and provide a commonly agreed understanding of it, which may be reused and shared across applications and groups. That is particularly important, as designers come from diverse backgrounds and their definition of the terms might be used for very different concepts. The established groups of concepts and terms that are identified build a so called taxonomy (Staab et al. 2001).

Data mapping

Data mapping is understood as the identification of data relationships as part of data lineage analysis. Vocabularies are related via mapping specifications that ought to be represented in different ways and formats, in order to facilitate the search and be able to address different end-users (Yoo & Kim 2002).

Defining the metadata

As stated before, metadata (the data about the data), is the first thing to determine when creating a knowledge base. The parameters given will not only define the documents but also establish the first indirect-relationships between documents.

The meta-informations are also called attributes. From them we can distinguish the ones with a pure identification mission, from the ones that are more descriptive or even document type specific. The description and classification of documents using these attributes facilitate the finding and/or providing of knowledge to a field. Figure 2-12 is an extraction from Lauer's (2010) work, were this classification and a couple of examples can be seen.

The conception of which content should be considered in the metadata varies between authors. The researchers Sang Bong Yoo and Yeongho Kim present their metadata in six different categories: Design, Registry, Document, Person, Part, and Approval. See figure 2-13.

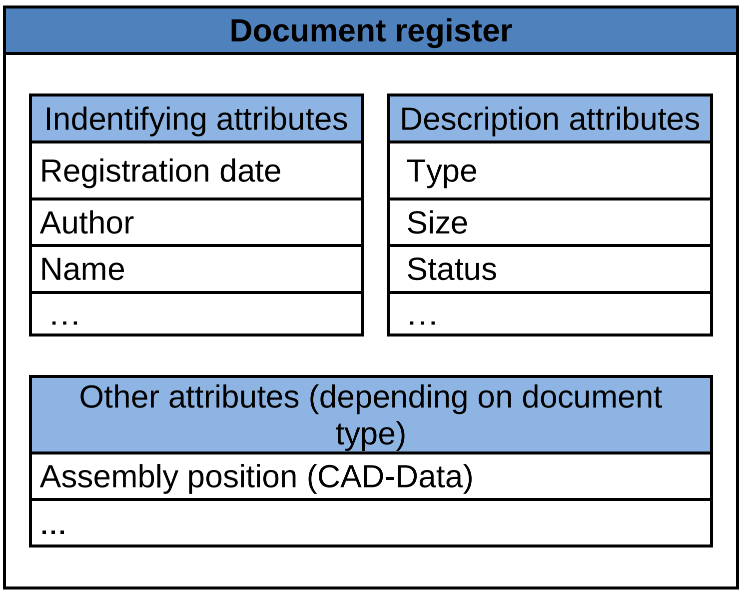


Figure 2-12: Attributes classification (Lauer 2010)

Table 1
Categories and elements of metadata

Category	Element name	Description	Category	Element name	Description
Design	fileName	File name	Part	partID	Part ID
	fileDesc	File description		partName	Part Name
	preprocessor	Preprocessor that generate the file		partDesc	Description
	schemaName	Schema name		level	Level of part structure
	url	URL location		quantity	Quantity
	fileSize	Size of the file		associatedDoc	Related document
Registry	registrarID	Registrar ID		associatedPerson	Related person
	registrarName	Name of registrar		containedBy	Part that contain this part
	registrarEmail	Email address		contains	Parts that this part contains
	registryDate	Registry date		approvalInfo	Approval information
Document	docID	Document ID			
	docName	Document name	Approval	approvalStatus	Approval status for the part
	docDesc	Description			
	docType	Document type		approvedBy	Person who approves
Person	personID	Person ID			
	personName	Person name		approvalType	Type of the approval
	employer	Employer			
	personRole	Role		approvalDate	Approval date

Figure 2-13: Categories and elements of metadata (Yoo & Kim 2002)

To decide which metadata better fit a given project, some issues are to be taken into account. For this purpose we can go back to Lauer's (2010) thesis, where this issue is covered in detail. The first task to be done is to deeply analyze what kind of knowledge is going to be generated during the process, i.e. which documents are going to arise from the project. Which kind of information can be found in these documents and how is it represented? How could they be characterized? Which are the parameters that would describe their content best?

To answer these questions Lauer (2010) proceeds to analyze a wide range of documents from different sources. To do so he will firstly differentiate the type of documents existing and consequently, by means of a software program, a text analysis will be automatically carried out. The point is to come up with document structures that reflex some differences and particularities of each document type. By studying the subject matter of the documents, a list of structural features could be created (Table 2-4).

Table 2-4: List of structural features regarding the documents analyzed (Translation of Lauer 2010)

Nr.	Structural feature	Nr.	Structural feature
1	Up-to-dateness	9	Source of information
2	Application expenses	10	Content
3	Frequence of use	11	Degree of concretization
4	Cost of creation	12	Phase belonging
5	Representation form	13	Relevancy
6	Display modes	14	Remaining development expenses
7	Creator	15	Comprehensibility
8	Function in information flow	16	Purpose in the product development process

In a similar way he will proceed analyzing every project phase. Taking into account the phases from the very beginning of the project until its end. At this point the activities taking place, their location through the process, the knowledge required at every stage, complexity and similar factors will be studied. So a list of process characteristics, for the most present phases in engineering product development, could be defined.

Table 2-5: List of process features regarding the documents analyzed (Translation of Lauer 2010)

Nr.	Process feature	Nr.	Process feature
1	Level of complexity	8	Product components
2	Work content	9	Component functions
3	Competencies	10	Descriptive product position
4	Tools	11	Constructive production
5	Methods	12	Evaluation
6	Process phases	13	Analysis
7	Purpose/Objective	14	Comparison

Attending to the hypotheses of his work, in order to facilitate the use of the knowledge base and provide the users with added value, documents and process phases must be related and therefore, the parameters defining both of them should be the same. In pursuance of this goal, the listed characteristics for both documents and processes should be compared and so come up with a new list of parameters that is able to describe the characteristics of both documents and processes. Nonetheless is important to keep in mind, that when developing a knowledge base, one of the prior focuses is the end-user and in order to provide him/her with a friendly base operation, the number of parameters should be limited. Lauer (2010) will limitate them to five in his work.

Table 2-6: Composition of the describing parameters for documents and processes. (Translation of Lauer 2010)

Description parameter	Document characteristics	Process characteristics
Content	Content	Work-content
Concretization degree	Concretization degree, phase location	Process phases
Remaining development expenses	Remaining development expenses	No directly comparable feature available
Usage	Purpose in the product development process	Purpose/Goal
Networking degree	Comprehensibility, extension	Complexity degree

Table 2-6 shows the final results that can be extracted from the extensive analysis of Lauer (2010). These five parameters are then considered to be necessary and sufficient to successfully describe the knowledge contained in every document and process stage.

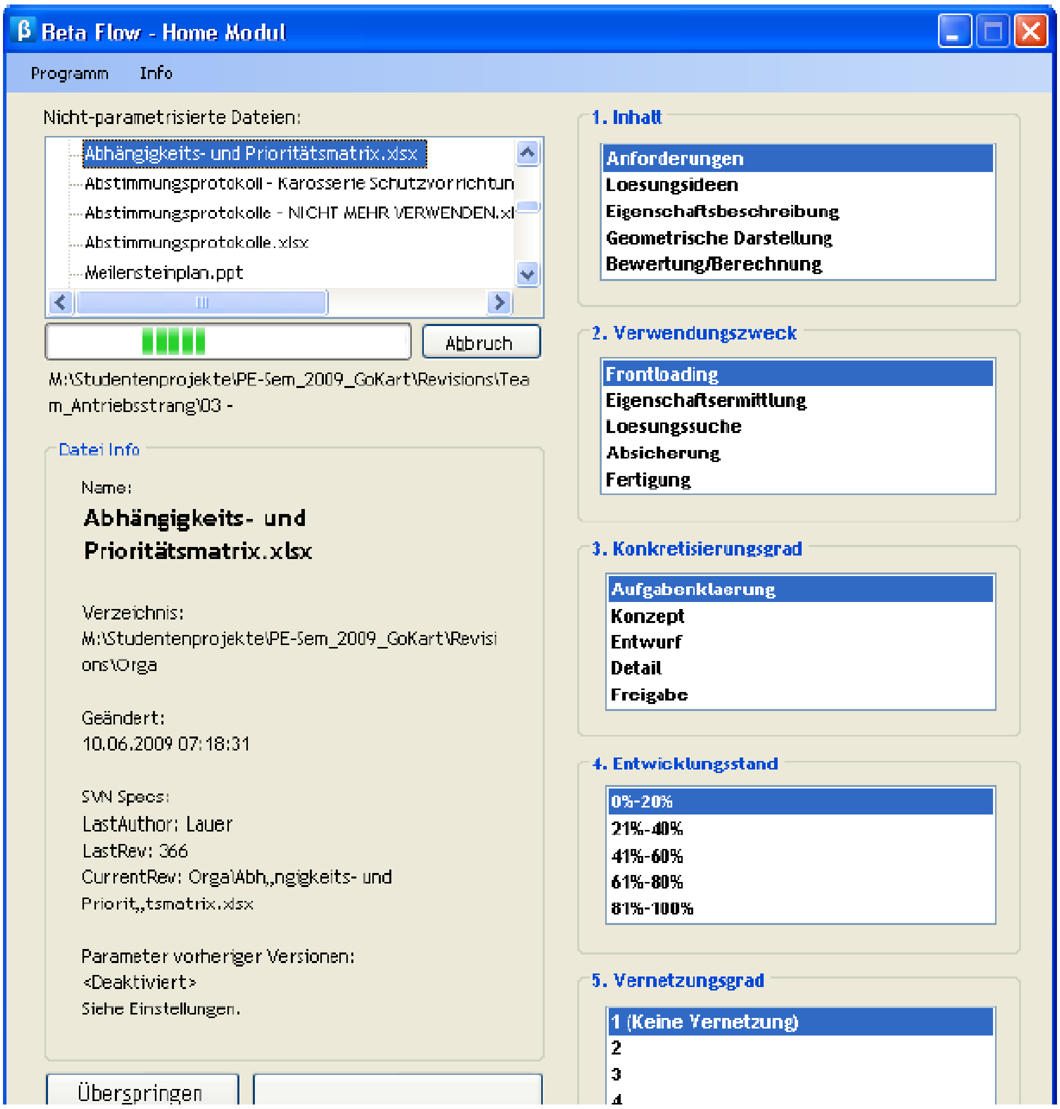


Figure 2-14: Lauer program implementation - 5 parameters

Figure 2-14 show us a window of Lauer´s (2010) implementation, where the five parameters can be defined by the user when documenting new knowledge.

Let's not forget that Lauer's (2010) thesis aims to design a dynamic knowledge base and that the process phases of the projects being considered are known and clearly defined (he doesn't work with an innovative engineering design project). That is why some of the analyses that he runs or some of the information that he has available, can not be found in the very beginning of an innovative project. In order for this issue not to affect the future implementation of knowledge bases of such projects, we will rely on Irlinger's (1998) appointment. He claims that the phases of a process can be connected to a document by defining the phase as one attribute more. In his work, he uses an object-oriented data model with attributes such as description, life stage, employee or name to support the information documentation during product development.

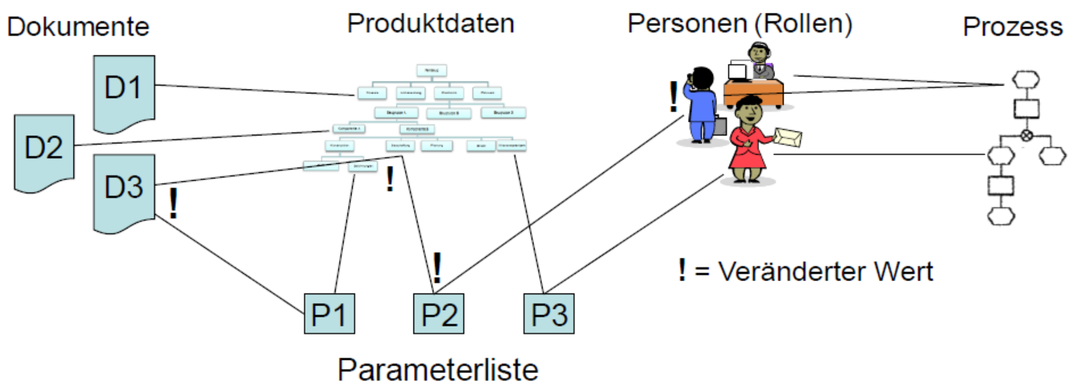


Figure 2-15: Parameter-based link between product data, people and processes (Translation of Schmitt 2000)

We can also find support to his work by reading Schmitt's (2000) work. For him a valid parameter is everything that helps describing a process-step better; variables whose value affects every related property of a product, i.e. shape, function, etc.
As we have seen, metadata can be very extensive and different depending on the type of project running and the kind documents being generated. The parameters given to describe the documents and so facilitate the search and documentation already stablishes some relationships between archives. Nonetheless is important to remember, that this attributes just generate indirect-connections and are defined to simplify the operation of the knowledge base. To establish direct connections between the documents in an organized and structured way, the ontology of the base has to be defined.

Creating an ontology

Ontologies are generally hierarchically organized and can be broken down into taxonomies, whose concepts can be arranged in classes and sub-classes that can be used for indexing. The challenge is then to identify the concepts that will be required for indexing design knowledge. (Ahmed 2005). It is very convenient for designers to count on a visible indexing structure to search for knowledge. Two main advantages are (1) assisting the designer in focusing their query through browsing or navigating the indexing structure; and (2) overcoming difficulties in search engines not understanding the context of a query. As search engines improve, they are better at retrieving relevant results to those expected. Visibility encourages less experienced designers to access knowledge in other ways they may have not considered searching for otherwise (Ahmed 2005).

Thanks to modelling-methods, the relationships between objects can be represented and so induce to transparency and a better comprehension. That is particularly interesting when dealing with big ramified connections trees (Helbig 2006).

That is why a detailed study of the content and hierarchy of ontology is a prior necessity. Ontologies have proven to be the right answer to the structuring and modelling problems by providing a formal conceptualization of a particular domain that is shared by a group of people in an organization. Moreover having more than one knowledge representative structure, as part of the indexing method is recommendable. The reason is to facilitate knowledge reuse by allowing a simpler access to the content by different ways. Authors like Conrad et al. (2007) criticizes that when regarding product development processes, most of the structures are function oriented and that makes difficult for users who are not highly familiarized with the product to access the knowledge.

A very clear and simple ontology to understand the operation of such a knowledge structuration system is the one shown in figure 2-16 about the animal kingdom. Here is to be appreciated, how the information can be represented in a hierarchical way, attending to different concretisation levels, and at the same time establish different kind of relationships between the nodes, connecting the knowledge in different ways and giving shape to the ontology-tree.

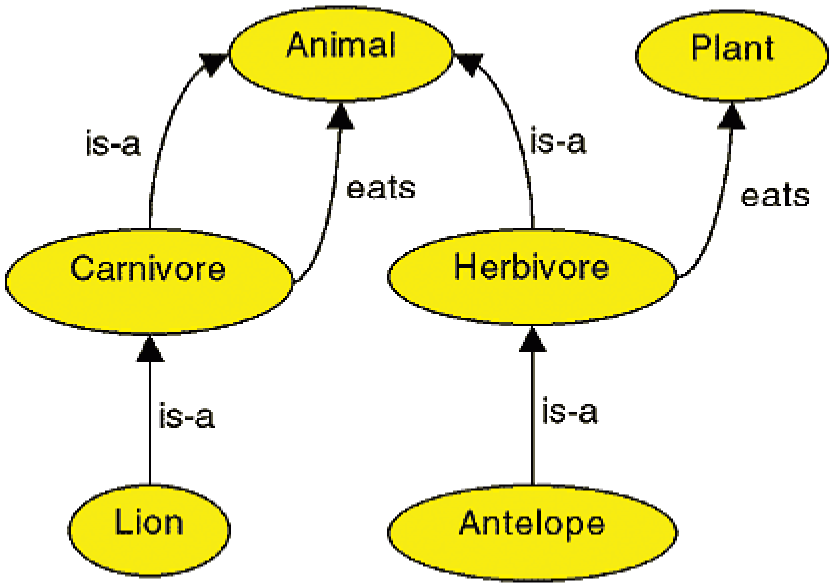


Figure 2-16: Simple example of an ontology – Animal kingdom (White 2005)

To help us to develop an ontology, the paper *Knowledge processes and ontologies* from Staab et al. (2001) suggest to follow the succeeding steps.

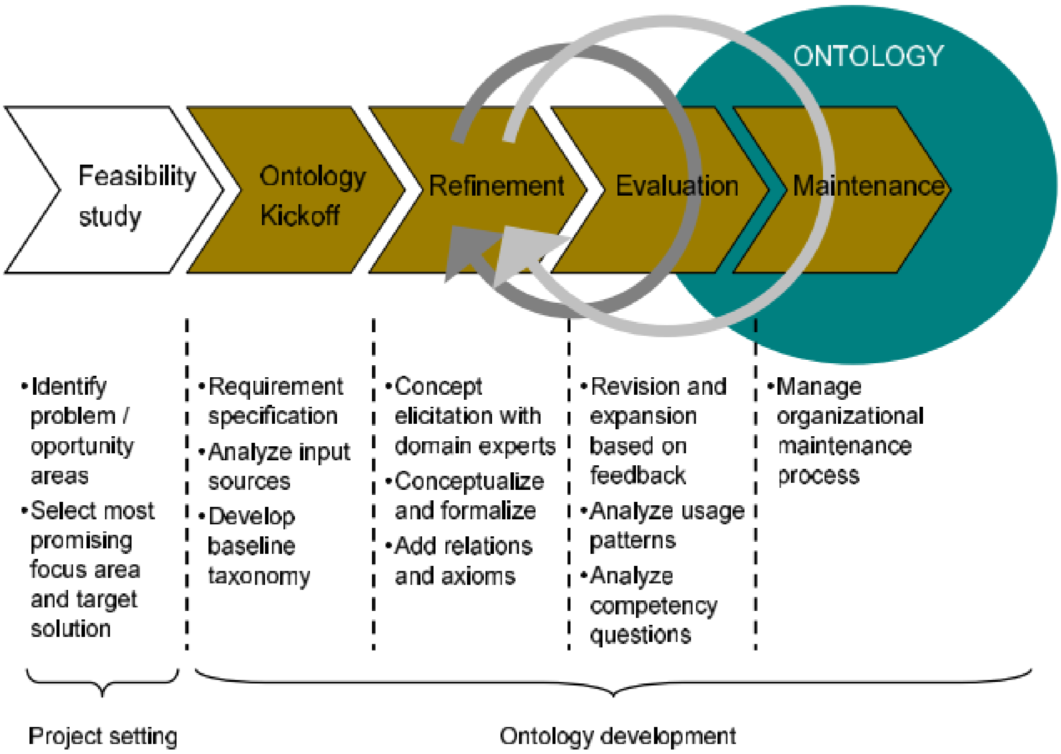


Figure 2-17: Steps to create an ontology (Staab et al. 2001)

Steffen Staab, Hans-Peter Schnurr and the rest of researchers who worked on this paper did a very detailed study that here will be summarized in the following eight bullet points, so that they provide a simple guideline for everyone willing to develop an ontology.

Table 2-7: Steps to create an ontology, with explanation (Staab et al. 2001)

Nr.	Step	Description
1	Identify the project areas	Get to know the project
2	Specify the ontology requirements	Determine end-users, context, etc.
3	Analyze the input sources	What kind of knowledge is to be documented?
4	Seek for Potentially reusable ontologies	The existence of former ontologies can speed the development process
5	Develop a taxonomy	How should this knowledge be structured? Define a general terminology
6	Add the relationship and connections between elements	Establish the links between terms
7	Evaluation	The ontology is tested in the target application environment. Feedback from users
8	Manage organizational maintenance	Keep the ontology updated with the project reality

Additionally the authors point out some characteristics of how such a system should perform. From their point of view, (1) every knowledge management system should support the collective gathering of information on the level of facts rather than documents; (2) integrating this gathering task smoothly into the daily activities. They should (3) allow to intelligently combine facts and establish relationships, (4) check new facts against the available background knowledge and (5) allow a multiple view access to the knowledge via a single entry portal; (6) allowing route derived facts back into the common workplace environment.

Finally it should be proven, that the designed ontology accomplished the five criteria that Gruber (1995) defines on his work *Toward principles for the design of ontologies used for knowledge sharing*. Those are clarity, coherence, extendibility, minimal encoding and minimal ontological commitment. As always in design problems, a trade-off should be carried out.

Clarity: To effectively communicate the intended meaning of defined terms. The definitions should be objective and independent of social or computational contexts.

Coherence: A sentence inferred from the axioms cannot contradict a definition.

Extendibility: An ontology should be designed to anticipate the uses of the share vocabulary. It should offer a conceptual foundation for a range of anticipated tasks, and let new terms for special uses be defined.

Minimal encoding bias: The conceptualization should be specified at the knowledge level without depending on a particular symbol-level encoding. (Encoding bias should be minimized because knowledge-sharing agents may be implemented in different systems or styles).

Minimal ontological commitment: An ontology should require the minimal ontological commitment sufficient to support the intended knowledge sharing activities. Give freedom to the parties committed to the ontology to specialize and instantiate the ontology as needed.

In general, ontologies tend to be hierarchically structured (Schulz 2002); nevertheless it is not the only possibility and the basis of the structuration can also be very different. From product structures, to phases, or the so called three level system (function, construction and behavior); the purpose of all of them is to facilitate the navigation trough the knowledge base and speed the provision of information. Attending to the project taking place and the specific knowledge base requirements, the one or another will be more suitable.

Building relationships – Data Mapping

After the metadata and ontology have been defined, one can create the relationships. The metadata has already described the documents to be located and the ontology has given a hierarchical structure to which the documents have to adapt. The last step is then to define the kind of relationships existing through the knowledge structure.

Hard and soft links are to be generated. The first ones support the structure established in the ontology and most of the times represent the connections between agreed standard activities. The soft linkages support the changing environment of a product development process and permit to cover specific information relation given topics. The kinds of relationships that the hard and soft linkages represent are also to be defined according to their meaning. Some examples could be: belong relationship, part of relationship, is relationship and so on.

Link types include:

- ***Precedence*** shows order of task execution, and likely iteration.
- ***Abstraction*** relates to the capability for a sequence of elements to be represented by a single element.
- ***Constraint*** links connect feature nodes, and show that a constraint exists.

Note that the term ‘feature’ is the name given to the data objects included in the process model. It bears no relation to other uses of the term ‘feature’ in the engineering domain (Baxter et al. 2007).

Mapping these relations is then the last step to allow the model to be visualized.

2.3 Lessons learned

From the chapters above, we have learned that knowledge reuse is far away from optimal. Damaging factors like a non-existent knowledge sharing culture, the lack of tools to document or the unknown of which knowledge is helpful and valuable for engineers have already been mentioned. With the aim of addressing some of these problems and make knowledge reuse a little bit more feasible, the lessons learned sessions were born. Indeed, these are for some authors, the key for knowledge reuse. (Prencipe & Tell, 2001).

Observing the team work of MyMINI and the kind of knowledge being generated (which did not include best practices or recommendations for future projects) it was considered, that lessons learned sessions could be of use. During the project, two lessons learned workshops took place; the first of them occurred after the first milestone and the second one by the end of the project. A further explanation of what the lessons learned are, their purposes and results obtained will be introduced in the following chapters.

2.3.1 Types of lessons learned

One of the existent tools for knowledge reuse to take place is the collection of lessons learned. They were originally conceived of as guidelines, tips, or checklists of what went right or wrong in a particular event (Stewart, 1997). Thus, definitions for lessons learned are still evolving to for example the one of the authors Secchi, Ciaschi, & Spence (1999), that reads: "*A lesson learned is a knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result*".

There are several types of lessons learned; as a matter of fact, each organization describes their own type according to their specific needs. Nonetheless, the underlying motivation is always the same, help to attain an organization's goals by collecting relevant knowledge.

Learning from former experiences is usually divided into process-based methods and documentation-based methods. The first ones stress the relevant steps and their sequence in course of a project's time line and the second ones focus on aspects of the content wise representation of the experiences and the storage of contents within the organization (Schindler & Eppler 2003).

Relevant studies have shown that not only the methods, but also the time when the lessons gathering takes place have an effect on the results obtained. That means that the impact of the knowledge reuse varies, according to the period of time when the lessons learned sessions were executed. That is why we are going to profound on the study of this kind of learning methodology.

When characterizing the lessons learned types, regarding the project phase on which they took place and their impact, we can distinguish between the following three groups.

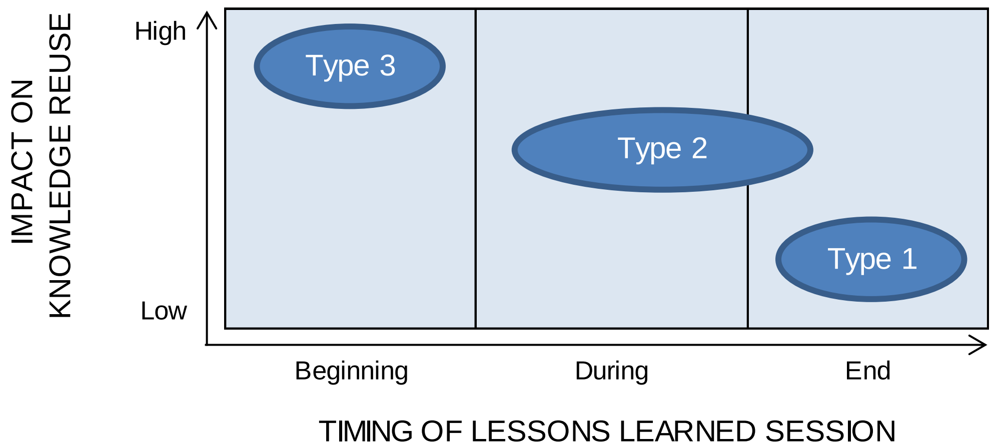


Figure 2-18: Lessons Learned classification according to impact of reuse and timing (Schact & Maedche. 2016)

Type 1: Cope with the past. This session is conducted at the end of a project. Usually the set of project-insights documented in these sessions either contain accusations against third parties or praises for the own work. Thus, within such a session, members get frustrated when the project didn't go well or they receive congratulations in case of success. In any case, the knowledge recorded has a low value, attending to the impact of knowledge reuse in an organization.

Type 2: Recapitulation. This type of sessions can be conducted when the project is completed or within the project's runtime. The session serves to collect project-related experiences in order to share them with other projects (inter-project learning) and to improve the performance of the current project (intra-project learning). In contrast to type 1 lessons learned sessions, here the team do not only focus on the past but also correspondingly generates a plan of action for the future. Running the type 2 during the project lifetime can improve the processes and enable a successful project completion; moreover the participants are aware of the benefit of such sessions and knowledge doesn't get lost in comparison to conducting the session at the end of the project, when some of the participants already are engaged in new projects.

Type 3: Preparation. This type of session has the highest effect regarding knowledge reuse. The session is conducted at the beginning of the project or at the beginning of a new milestone. The purpose is that the participants share their gathered experiences and so draw attention on possible traps and issues. (Brainstorming or storytelling methods are commonly used during this kind of sessions). The final objective is to prevent already known situations challenging the project.

This previous section is a summary of the work of Schacht & Maedche (2016).

2.3.2 Extraction and use methodologies

Based on these lessons learned types and their respective impact in terms of knowledge reuse, the researchers Silvia Schacht and Alexander Maedche (2016) have developed a new knowledge reuse methodology. First of all they designed, what they called, the "double-cycled lessons learned process".

Depending on the purpose of the lessons learned session, projects have to follow one of the cycles. The processes of both cycles contain all necessary activities to conduct effective lessons learned sessions. As it can be seen, the cycles do not include the type of lessons learned 1. The authors considered this type of lesson the least valuable one and therefore did not propose a methodology to carry it out.

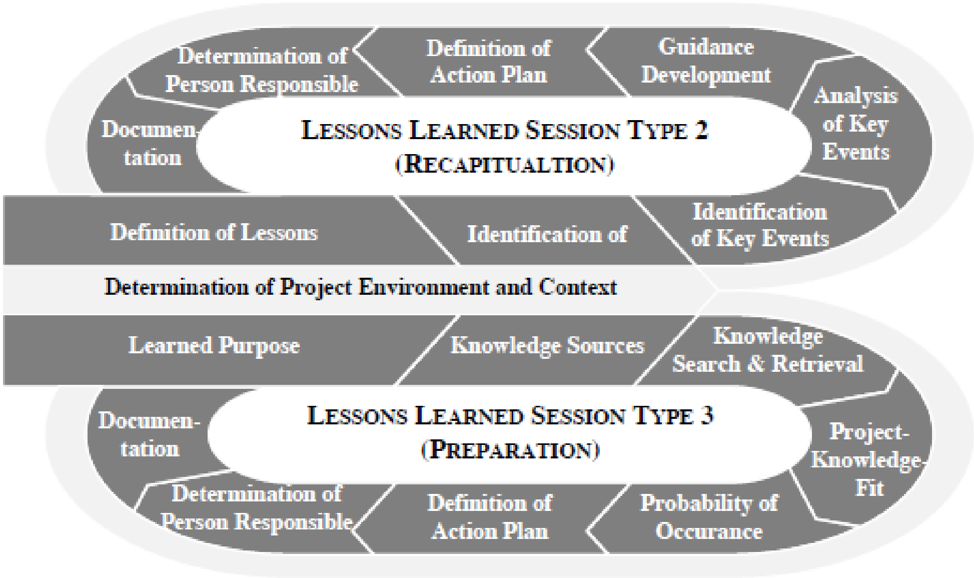


Figure 2-19: Double-Cycled Lessons learned process (Schact & Maedche 2016)

The first step begins with the project teams being aware of the initial situation and context of the project. Before the start of the session, they also must be able to answer the questions, what is the main purpose of this project? Who are its stakeholders? And thus, lead the session according to all these objectives and influences. The aim of this first step is members to speak the same language regarding the project environment, and to be able to recognize suitable sources of knowledge that may provide valuable insights. This step is independent of the final purpose of the session taking place and must be always carried out. (Set the bases of the current project and refresh the context).

When running a lessons learned type 2 the common purpose is the recapitulation of the project in order to gather insights that might be helpful for other projects (inter-project learning) or even for the actual, running project (intra-project learning). The reassessment of project context serves as good entry point into the lessons learned session. Once all team members are aware of the project environment, the brainstorming phase begins. This phase pretends to recognize project-related events which had a significant impact on the project's success or failure. Various creativity methods can support this process. The results of the analysis phase will be used to establish a plan of action for every particular event, to avoid or foster them and thus their positive or negative influence. Finally the findings will be documented and the lessons learned stored at a central knowledge base, available for every employee.

When the focus is to increase knowledge reuse within an organization, the lessons learned type 3 is more effective. That is brainstorming on possible risks and collecting prior experiences, from which current projects can benefit and be prepared for. In this process again, all participants must have in mind the project's contextual information so that they can identify knowledge sources that fit the actual requirements. Once this knowledge is identified it will be rated, according to the probability of repetition and impact in the project. Risk management procedures can support this phase. Afterwards, responsibilities can be shared and determined. Similarly to the prior lessons learned type, the finding will be stored and documented in a central knowledge base.

On this interesting new model is that our lessons learned workshops are going to be based on.

2.3.3 Role definition

Part of the new knowledge reuse methodology of the authors; include the definition of two roles that would lead the sessions.

The first role identified as "lessons learned expert" possess the methodological knowledge on capturing, documenting, storing, transferring and maintaining project insight. He/She will act as neutral moderator, assuring every participant has the same rights and duties, and this way allowing an equal participation furthermore an extensive collection of experiences.

The second role, called "topic expert", is the one having prior experience in the field and therefore content knowledge. He/She will act as a consultant, supporting the team in the brainstorms and sharing his/her experiences. Moreover he could also help to determine which members do have the required knowledge to participate in the session and obtain the most of it.

3. Analysis of the team and its work

3.1 Presentation of the team and its objectives

The MyMINI construction project is a collaboration between the car manufacturer - BMW, and the Product Development department from the Technical University of Munich - PE.

The aim of this cooperation is to generate innovative ideas, by means of agile methodologies, for the car interior involving individualization and digitalization fields. The motivation of the work is to prove, that also big companies like BMW can innovate by listening their customers' needs and reacting rapidly to the changing environment.

The observation of the current trends and technology developments are prerequisites of the project. So are the contact with BMW experts and MINI drivers to truly address the customer needs and company image.

To achieve this objective, ten students and two assistant forces from the Technical University of Munich have worked together during six months. The purpose is that these ten students specialize themselves in different topics such as customer experience, agile management, product architecture or vehicle data, and so be able to generate a synergy to be reflected in the final output of the project.

Particular attention will be paid to car zones where innovation could happen and to gaps to fulfil in terms of client necessities. Listening to MINI customer's wishes and studying their daily life will help identifying current situations that could be eased or improve and discover unexplored areas where value can be added. This all noticing how the new technologies evolve, and foreseeing how the near future may look like.
In contrast to a full new-product roll-out, this project will be in a learning launch base conducted. This means quickly and inexpensively gathering market-driven data to determine whether a growth idea has enough merit to warrant detailed investigation with the commitment of further time, people and resources (Hess & Liedtka 2016).

3.2 Introduction to the agile methodology

The agile development methodology was born as a necessity to face the rapidly changing environment and be able to keep on track with it. That is why this methodology is called adaptive, as it is ready to acclimate to the dynamic world of today.

Being a people-oriented methodology is other of its main properties. Agile development approaches rely heavily on socialization through communication and collaboration to access and share tacit knowledge within the project team. Usually these teams are cross-functional. That means drawing together individuals from different backgrounds, all performing defined roles to achieve a common objective; rotations from one role to another are common. This kind of team, work especially well under uncertain environments with unknown requirements. This fits perfectly with agile methodologies and their need to adapt to every situation and facilitate the knowledge transfer (Fowler & Highsmith 2001).

That is not the only point where agile methods include people. Actually, as its own Manifesto states, the highest priority of this working methodology is to satisfy the customer by continuously providing him value, shortening the delivery cycle times and incrementally (and iterative) improving the outputs. To do so, customer involvement is a key factor for project success. Requirements and domain knowledge will be through customers acquired and the iterative development will be driven by getting rapid feedback. This close collaboration allows continuous learning and better understanding to take place. Customer accessibility will be therefore a critical factor for such methodologies (Paetsch et al. 2003).

As already mentioned, continuous learning is considered one of the fundamental pillars of the agile methodologies. To facilitate learning among developers, agile methods use daily/weekly stand-up meetings, pair programming, pair rotation and collective ownership. They believe that learning or the internalization of explicit knowledge is a social process, as it mainly takes place through interactions with others – Tacit knowledge. Moreover, the use of retrospective methods, like post-sprint meetings, reflection workshops, post-iteration phases, and review phases also supports continuous learning, helping with the identification of success factors and obstacles; which represents very valuable knowledge also at a project level (Chau et al. 2003).

When regarding knowledge generation, documentation is a topic that needs to be treated. Agile teams don´t believe in repositories as sources of knowledge. They claim that those do not support communication and collaboration within the team members. Nevertheless documentation is still needed to keep all members informed, digitalize the new findings and avoid mistakes or duplicated work (Chau et al. 2003). The scope of the documentation is often very limited and focuses on the core aspects of the system. This increases the chances that the documentation can be kept up to date. Moreover in comparison to classical documentation processes, in agile projects content can be posted without undergoing rigorous review-approval processes. The informal nature of this way of working places great responsibility on the shoulders of every team member to ensure the quality of the knowledge stored (Chau et al. 2003).

3.2.1 Scrum as tool

A very useful methodology of working for such kind of team is Scrum. Scrum is a tool for managing the product development process, by applying ideas on flexibility, adaptability and productivity. Scrum focuses on how a team should work together to produce quality work in a changing environment (Paetsch et al. 2003).

A key principle of Scrum is recognizing that customer needs are volatile and therefore the adaptability to these changes is a must. Scrum does not focus in fully understanding the new problem, but in quickly providing a new solution, to so get feedback and properly response to the emerging requirements. This mindset supports the principle of failing fast and cheap. It is worthy for designers to rapidly show their first prototypes, in order to see if they respond to a real customer need and iterate with the feedback given. In case the hypothesis done was wrong, it's better to know it from the beginning, when little time, effort and money have been invested.

The main Scrum techniques are the product backlog, sprints, and daily scrums. These techniques encourage self-organization, close collaboration between members and daily face-to-face communication.

Product backlog. All requirements regarded as necessary or useful for the product are listed in the product backlog. It contains a prioritized list of all features, functions, enhancements, and bugs. No changes are allowed in the backlog during the sprint, but there is absolute flexibility for the customer to reprioritize the requirements for the next sprint.

Sprint. A time period (typically 1–4 weeks) in which development occurs on a set of product backlog items that the team has committed to.

Sprint review. At the end of the sprint a meeting is held to demonstrate the new functionality to the customer and solicit feedback.

Daily Scrum meeting. 15-minute strictly time-boxed meetings to set the context for the coming day's work. This keeps the discussion brisk but relevant. (In MyMINI project Weekly Scrum meetings were held).

In Scrum all team members have to self-organize their work and write down in the board their tasks and their accomplishment, so that every member can see how the product is evolving in every area (Paetsch et al. 2003).

This tool, based on iterations and incremental evolutions rely on the accessibility of the customer for its success. It perfectly fits the agile projects' requirements as it emphasizes on people, communication and collaboration and excels in facilitating the practice of knowledge sharing.

In the following figures the scrum boards of both teams can be seen. The main procedure is for both of them the same, as just explained above, but each designed the most suitable post-it color-code according to their requirements and team working structurations.

Figure 3-1: Scrum board - Team Modular

Figure 3-2: Scrum board - Team MoodMusic

3.3 Knowledge generation

Through the six-month project, as well team documentation as individual documentation for the personal themes, have been generated. Starting from the most basic weekly documentation where the goals and methods applied are described, to the most detailed CAD-files where the end-product can be observed.

Through the project around 600 documents were generated. The type and content of these, change according to the project phases adapting to the needs of the designers at the specific moment. In the team cloud, text documents, images, video and audio samples, power point presentations, excel charts, CAD and Catia models, and some other type of archives were stored. The content documented was very mixed, going from analysis, to customer questionnaires, product sketches and end-designs, also being a lot of team managerial documentation stored.

As stated before, the team stored all the generated knowledge in a cloud where they had different folders. In figure 3-3, are those to be seen.

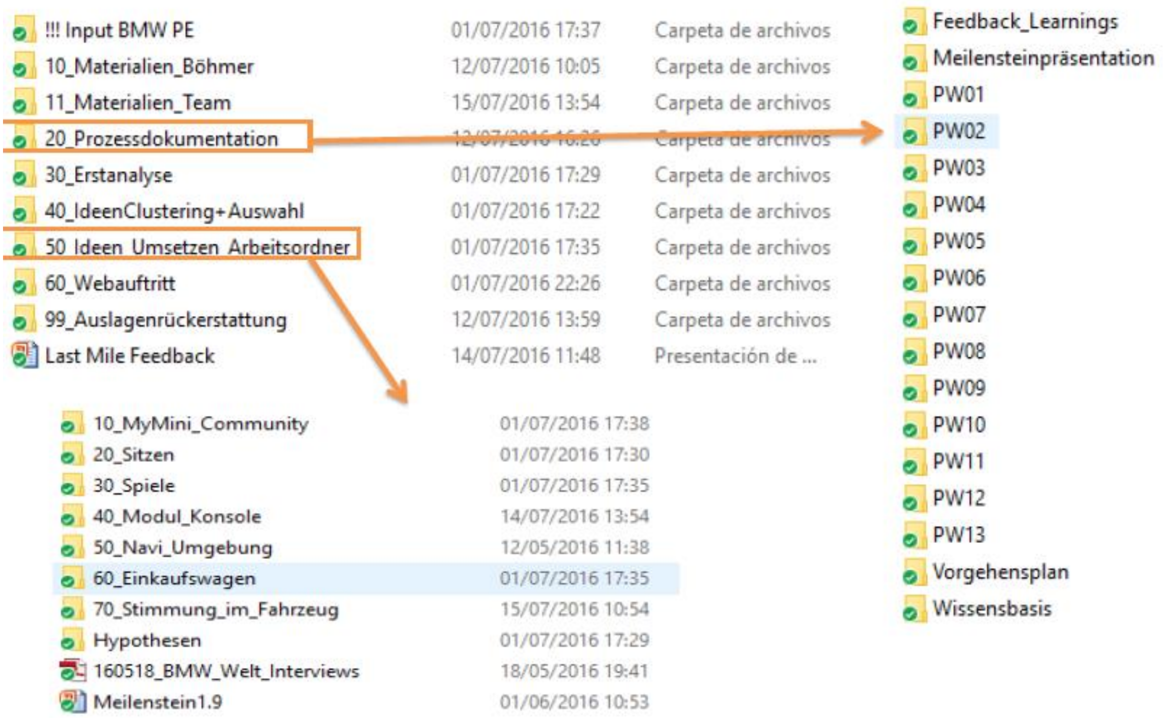


Figure 3-3: MyMINI Project Cloud. Knowledge documentation

The first window contained general folders regarding knowledge about: Team material, process documentation, first analyses, idea selection, idea implementation and website operation. Once inside of these folders, more concrete knowledge could be found.

As stated before, the team work was based on agile methodologies. This is reflected in the documentation by having first a collection of research knowledge to recognize the innovation possibilities; with the consequent iteration or death of the emerging ideas. Process always supported by the customer feedback obtained by different means according to the feature to be evaluated. Parallel to these project stages, the division of the main team into two teams that developed two different concepts also shaped the content of the cloud. All documents from the first milestone onwards will be related to the MoodMusic idea or to the Modular idea.

Both teams generated several knowledge and every team member had the right and duty to document and edit the knowledge he/she considered necessary. Nonetheless, the knowledge management expert of the team had to assure that some minimum requirements were being met in order to allow a future knowledge reuse. Therefore two key documents were created. On the one hand, so as to fulfil the documentation requirements that the tutors demanded and gather the most representative events of the week, a “Sprint” document was designed. On the other hand, with the purpose of simplifying the search of project outsiders by providing them with context about an idea, an “Idea Form” explaining the main features and value added of each concept-proposal was designed.

- ***Sprint document:*** This document was fulfilled by one person of each team every sprint/week. The document contained information about the objectives of the sprint for each team, the methodologies applied to achieve them, the problems faced and learnings discovered. Also the technical issues were considered, as well as the solutions found for these. The sources of information employed and the information lacking (but desired by the engineers) were written down too. Finishing the documentation by approximating the project current progress in percentage and recalling the positive and negative influence factors having an impact in the goal achievement of the sprint. (In annex A28 an example of this document can be seen). (Künzel, 2016), (Master Thesis of Manuel Hoehn, 2016).
- ***Idea form:*** This document was fulfilled by the end of every milestone for all the ideas being developed during that period. It contained the main information about the idea such as: name, product description, photos, materials used, manufacturing procedure and important notes to take into account about previous prototypes or relevant learnings collected. (In annex A29 an example of this document can be seen).

Complementarily to these documents, the theses of two team members will report important findings that could be useful in terms of knowledge reuse for future projects. Therefore when implementing the knowledge base they will also be taken into account.
On the one hand, Manuel Hoehn (Master Thesis, 2016) worked researching the information lacking the team during the whole project. He paid attention to which information was not accessible for the designers and how could have it helped in case of possessing it. Attending to the three main milestones, he did three evaluations; so as to analyse if the designers were satisfied with the knowledge they had until the moment to develop their idea, or if they would have liked to possess more or different information to approach the task. The results of this thesis will be very interesting for knowledge reuse, as knowing what the designers need, is one of the keys to provide relevant knowledge that can help them with their work. These findings will be stored under the concept: lessons learned, category: technical, subcategory: interviews1/2/3. (See chapter 4.3 about the knowledge structuration).

On the other hand, Kurz (2016) played the role of the change-management expert or requirements expert. In his case, he analysed which requirements the team had at the beginning and how they evolved as the project did so. He also studied how the requirements were approached and evaluated by the team. In his thesis he delivers an improvement proposal about how teams in product development projects can better address the requirements in a more efficient way. This information will also be valuable for coming projects and therefore a reference to his master thesis will be found under the concept: lessons learned, category: feedback requirements. (See chapter 4.3 about the knowledge structuration).

These concrete documents together with the remainder knowledge generated cover the content of the MyMINI cloud and represent the documents that will be available for the knowledge base end-users. Already here it is palpable, that the knowledge stored in the base goes far beyond the geometrical data of the traditional ones. This knowledge is focused on facts rather on documents (as suggested Staab et al. 2001) with an important context-centred approach, which relies on methods, argumentations and a broad range of files supporting and explaining every step of an idea evolution.

3.4 Role of the knowledge expert

The project definition aimed all ten students to cooperate in the innovation project and parallel to write their own thesis them; so that together we could create a synergic effect that benefits the project output. In my case, I took care of the knowledge management aspects and the implementation of a knowledge base.

The knowledge base expert role implies working together with the team, to better understand what the requirements in such projects are. Another responsibility is to take care of the knowledge management process during the project, by analysing and organising the knowledge being generated, to afterwards implement an appropriate knowledge base that empowers the knowledge reuse for future projects.

Moreover, knowing that some knowledge will never be documented, mostly because the team members don’t recognise it as new knowledge or because it attains managerial aspects; two lessons learned workshops will be carried out. The first one, just after the first presentation, to understand how we were performing until that moment and how to proceed in the coming months; and the second one after the last presentation, to evaluate how good the outputs were and which recommendations could be done for future projects.

3.5 Requirements for a knowledge base in agile projects

Through this chapter we have learnt how agile projects work, how they communicate, furthermore, how their documentation requirements look like. Some of the key factors being recognized as having a direct impact in the base, that these teams need, are the following.
In terms of the conception of this work methodology, it is important to keep in mind that these teams are customer-centred. Meaning that they base their work on having narrow relationships with customers, so that they can truly observe and understand their needs and so create value for them. Nevertheless, in this rapidly changing environment of today, customer needs are not clear, and in order to stay one step ahead to surprise and anticipate customers necessities, designers base their work on many assumptions. They aim to fail quick and cheap so that they can validate their assumptions and learn by means of iterations.

These factors require from knowledge bases a great flexibility, so that they can represent all these changes and iterations during the project.
Moreover, we have seen that agile teams use to be cross-functional and commonly characterized as very communicative and tacit knowledge dependent. The documentation of their findings is usually scarce and collects only the most important knowledge. To do so, every team member is responsible of documenting and the way to support them with a base is by making this process simple and fast, so that first of all everyone is capable to use it, and secondly that designers can quickly go back to their creative tasks. This way the documentation process should be encouraged. For this purpose it will also be important to make available an explanation of terms and relationships, as well as a learning session to properly understand the application of the base and take the most profit of it.

According to the authors of *An evaluation of the degree of agility in six agile methods and its applicability for method engineering* (Qumer & Henderson-Sellers 2008) agility can be described with the six following attributes: speed, flexibility, learning, member's responsibility and leanness. All six factors will be addressed in the coming base definition.

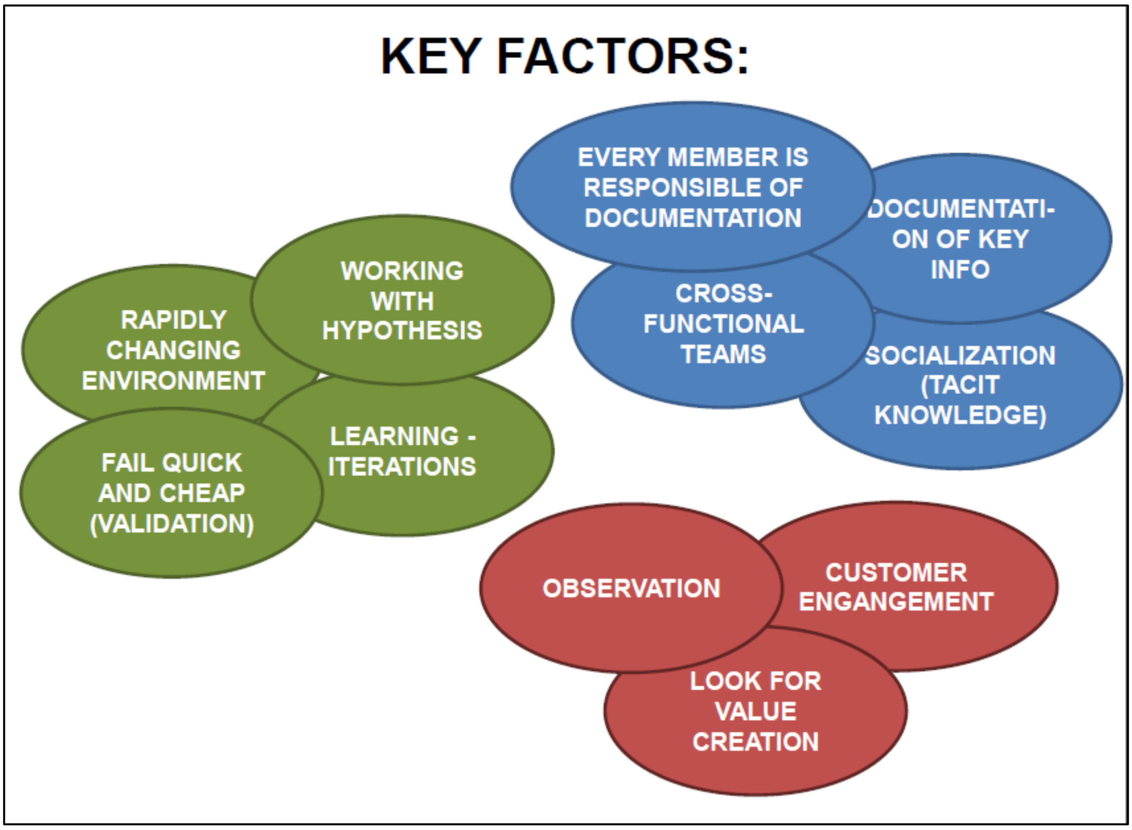


Figure 3-4: Key factors of agile working teams

3.5.1 Feedback from the team regarding their current knowledge repository

The knowledge repository with which the team has worked is composed of different folders placed in a cloud. Every member is free to add, edit or remove any document or folder from the cloud. During the project, the team members have been organising themselves the repository and adapting it to their necessities.
Before starting to develop the new knowledge base model, I decided to talk to the team

members about the current knowledge base and ask them for feedback about its operation and performance.
Even though none of them was really upset about the base, neither were they happy with it. They were aware that a lot of time was being consumed when looking for documents. The structure was not clear enough and therefore one document could fit in more than one folder. That was a problem when trying to add a new document or look for an old one. Moreover, they claimed that it was time consuming to look for documents by clicking through folders, when they knew from the beginning where the document was. A filtering system could have been used.

A couple of wishes more that they formalized were:

- A time/phase frame, to ease the search and allow seeing all archives generated at a given period of time (speed the search). Furthermore to be able to visualize the evolution of documents or ideas.
- Establishing connections between related documents, being able to collect all the information at a glance.

It was interesting to prove, that the theoretical requirements found in chapter 2 really match the designer's needs, at least they do match what the designers expressed as their requirements. In next chapters we will evaluate, if the requirements were properly addressed with the implementation of the base and if the necessities expressed by the designers really are what they expected from the base performance. (It is a problem in research studies, that people don't act like they say they do, and their stated requirements might not really satisfy the way they really would use the base (Knapp et al. 1979)).

4. Creation of a knowledge base

Once the theoretical background and project environment have been defined, is time to present the knowledge base design. In chapter 4.1 the requirements will be set, chapters 4.2, 4.3 and 4.4 include the definition of metadata, ontology and connections; finishing this chapter with an explanation of the implementation and examples of the base's use.

4.1 Set of requirements for the project knowledge base

From chapter 2 we learned some of the requirements of knowledge bases.
On the one hand the eight requirements of Lauer (2010): (1) Adjusted to demand, (2) process oriented, (3) across phases, (4) across levels, (5) different perspectives, (6) simple application, (7) added value must be perceptible, (8) the search function must be supported. On the other hand the contributions of other authors were also considered. Stating requirements as: The usefulness for as many end-users as possible, a simple structure, a simple visualization with multiple representation options, an explanation of the meaning of terms and relationships, the need of maintaining the base updated, or having a time frame (phases).

Regardless of possible differences between authors and their works, a meeting point in all their studies is the need to create a base being appropriate for the given process. Not only the project development must be perfectly understood, but the culture and company ways of working must be considered.

Furthermore, chapter 3.5 has enlightened us with the requirements of agile bases in order to adapt to their working philosophy. Now that both the classic knowledge base requirements and the ones of agile documentation have been presented, the combination of requirements for the knowledge base purpose of this thesis can be set.

A recompilation of the requirements can be seen in table 4-1. The objective will be to address as many requirements as possible in the base implementation and afterwards evaluate, if the end-users really perceived this requirements as fulfilled.

Another point to discuss is the topic presented in chapter 2.1.1. We went through the differences between data, information and knowledge. It was also stated, that data and information repositories are easily found, as no or little reflexion is needed to store such kind of material. Nonetheless, working with knowledge involved a deeper reflexion and topic understanding. To generate knowledge, information had to be comprehended and developed. Going further, to intelligently store knowledge to be posteriorly reused, a much more complex process is required; not only the knowledge contained must be understood, but also the situations in which this knowledge might be helpful. The purpose is by means of this deep understanding, to design a structure able to cover all this knowledge and make it available for its reuse in future projects. Noticeably, this kind of repositories precise much more work and maestri and therefore they are not common.

Table 4-1: Composition of the requirements set by knowledge base theories and agile methodologies

Nr.	Requirement	Source
1	Adjusted to demand	Lauer 2010, Milton 2007
2	Process oriented	Lauer 2010
3	Across phases + Time frame	Lauer 2010 & Team
4	Across levels	Lauer 2010
5	Different perspectives	Lauer 2010 & Milton 2007
6	Simplicity in its use	Lauer 2010 & Hamid R. Nemati et al. 2002, David M. Steiger, Milton 2007
7	Added value must be perceptible	Lauer 2010, Milton 2007
8	The search function must be supported	Lauer 2010 &Team
9	Usefulness for as many end-users as possible	Milton 2007, Chou et al. 2007, Conrad et al. 2007
10	Visual structure with multiple representations	Elsevier Ltd., Chou et al. 2007, Conrad et al. 2007, Staab et al 2001, Ahmed 2005, Helbig 2006
11	All terms and type of relationships must be distinguishable and properly explained in a legend	Milton 2007, Gruber 1995
12	Need of keeping it updated	Hamid R. Nemati and David M. Steiger, Milton 2007, Gruber 1995
13	Fast to register and use knowledge	Team & Agile Manifesto
14	Flexible to allow development iterations	Agile Manifesto

But, how is performing the base of this thesis about it? The aim of this work is to develop a knowledge base that supports the designer's activities in a more effective way as the existent ones by easing the knowledge reuse process. That being said, the repository we are aiming to design falls into the second category we mentioned. During this thesis, a detailed study of the work being done and the knowledge being generated has been carefully carried out, so that a profound understanding of the whole is achieved. The intention of the base is then clear, but what about the documents stored in it? Is only knowledge being stored? How can we be sure, that only knowledge is entering the base? Answer these questions is not easy for any repository, as the boarders between data and information or information and knowledge are not always precisely defined. In this concrete case, let's recall that MyMINI Project works under the agile methodology. Regarding the documentation, this meant only storing the most important and relevant facts of the development process. Relying on this assumption, we can be sure that no data is going to enter the base of this thesis. All documents being stored, had previously be worked by a team member or they represent valuable information for the decision making process. Hence, we can consider that the knowledge base of MyMINI Project will mainly consist of knowledge, with the contribution of single amounts of information required to set the context of the idea development and support the designing procedure. The documents listed in table 4-2 show a clear image, that the input being stored in the base does not contain simple data but a much more developed content.

4.2 Definition of the metadata

As already stated in chapter 2.2.4, the metadata is the first thing to determine when designing a knowledge base. The metadata, as it has already been explained, represents the data of the data and accomplishes the double function of condensing and codifying knowledge, while establishing the first relationships. To determine the metadata of this concrete project, they methodology explained by Lauer (2010) in his thesis will be followed. (See chapter 2.2.4)

The first step to approach the definition of the metadata is to analyse the documents being generated. The type of documents, their content and main characteristics are to be determined, so as to be able to gather in the base all the needed parameters to accurately describe the knowledge contained in the archives. (Unluckily it was not possible to replicate the text analysis that Lauer carried out in his thesis. This step could not be taken into account and he had to rely on the document analysis).

In this concrete work, every document generated during the project will be considered as knowledge (or valuable information) and therefore, it will be gathered in the base.

The same should be done with the project phases, in order to prove that both can be described by means of the same parameters.

For the purpose of this thesis, it will be assumed that the parameters defined by Lauer (2010) are suitable for this kind of projects, as he had a broad provision of information and sources in his analysis. As a reminder, these parameters come from summarizing the structural features table (table 2-4) and the process features table (table 2-5) in a way that all properties are considered. The final parameters to work with are: Content, concretization degree, remaining development expenses, usage and network degree. These are represented in the table 2-6. Hence, we just have to make sure that also the documents and phases of this project are well defined by those parameters.

On the one hand, the documents generated were the following: Text documents, images, videos, CATIA and CAD archives, PowerPoints, Excel charts, PDF documents, and in particular cases a couple of more formats. This documents mainly contained knowledge about the environment (customer, product, competitors and trends analysis), knowledge about the different product iterations (customer's feedback in the form of questionnaires, social media or experiment boards), knowledge about the diverse product ideas (prototypes, story boards, marketing material, business models, or forms describing the product and functionalities), knowledge regarding team managerial issues, and lastly knowledge regarding the lessons learned discovered during the project.

Regarding the phases, as usually in agile projects, they consist on iterations. To simplify the comprehension and facilitate the reuse of the base, the number of iterations will be reduced to two, attending to the two biggest milestones taking place through the project (recall chapter 3.3). The project phases will be then three. Research, first iteration and second iteration.

At the beginning of the project (research stage) all students worked together analysing interesting fields of action and current trends to be exploited. It was after the first milestone when two teams were created and started developing different concepts. This led to a different organisation regarding the internal iteration and phases.

Figure 4-1: MyMINI Project development phases

Figure 4-2: Development phases of the idea MoodMusic

Figure 4-3: Development phases of the idea Modular

Notice that even when the phases of the different ideas might be different ordered (every development process is different), the name and significance given to the each of them are the same regardless of the timeline picked.

In order for all these documents and phases to be defined, fourteen parameters were selected. Six of them relate the fields of document location and registry (metadata) and the second eight shape the base structure and help to fulfil the Lauer's (2010) parameters (table 2-6).

All fourteen parameters were designed for this concrete base. The ones relating the metadata (1 to 6) were extracted from the broad literature research, considering the necessities of the project (Recall figures 2-12 and 2-13). The rest eight parameters were conceived to support the ontology that will structure the base and represent the knowledge. The selection of these eight parameters took into account the five key parameters of Lauer (table 2-6), so that they all got implemented.

Here the theories shown in chapter 2.2.4 have been applied. The contribution of Irlinger (1998) suggesting to enter the process phases as an attribute of a given document, or the statement of Schmitt (2000), who points out that the parameters or attributes are every quality helping to describe a specific document, are some examples taken into account when selecting the metadata.

1. Name
2. Description
3. Size
4. Type
5. Author
6. Registration date
7. Status
8. Concept
9. Category
10. Subcategory
11. Idea related
12. Subcategory related
13. Phase
14. Sub-phase

The first six parameters are the most typical ones in classical knowledge bases. They aim to accomplish the most basic functions, giving a certain document attributes to be identified, located and described. (Identification and descriptive attributes of the metadata – See chapter 2.2.4).
The parameters seven to fourteen come from the ontology defined and consequently will be explained in the next chapter.

4.3 Definition of the ontology

Keeping on with the methodology defined in chapter 2.2.4, the following step will be to define the ontology. The purpose of the ontology is to set a base structure and a common shared terminology between all end-users. As we learnt from the previous chapters creating ontologies is extremely complex and requires a perfect understanding of the whole system and an organized mind to be able to set all parameters with their different and significant terminologies, in a structure that can be perceived as logic and valid for as many end-users as possible. Keeping in mind that it should be extendible, if new knowledge in the existing or new fields appears, and consequently has to be documented and stored.

Most designers tend to reuse ontologies from previous projects or adapt the standard ones, so they can save a lot of time and be sure that some minimal requirements are being fulfilled. Nonetheless, the works about knowledge management and knowledge reuse in innovation design are scarce and the ontologies from such projects almost inexistent. To design the ontology for this base was then needed to start from scratch. To do so, the seven-step process of Staab et al. (2001) will be conducted. It was decided to choose their guidelines, as from the many literature regarding ontologies, they were almost the only ones that approached the whole process creation from the very beginning to the very end, doing it in a comprehensible way that could be understandable for every reader of this work. (Recall chapter 2.2.4).

1. ***Identify the project areas***
   Now that scopes, objectives of the project and methodologies employed have been presented, we have a better understanding of the team goals and requirements to achieve them. The purpose of the ontology is to support designers to achieve their objectives by means of a suitable ontology.

2. ***Specify the ontology requirements***
   On the one hand, the already set requirements for the base have to be supported (Table 4-1). On the other hand, for the purpose of this thesis we will consider the end-user to be a student in any case. This student could have been involved in the project or be an outsider. Regarding the context, also two situations will be taken into account; using the base during the running project or doing so in the future.

3. ***Analyse the input sources***
   Chapters 3.3 and 4.2, already mentioned the documents being generated during this project. Table 4-2 shows a recompilation of the input sources.

Table 4-2: Recompilation of documents and input sources in MyMINI knowledge base

Input sources/Documents	Document type
Road Map & Goal setting	Word, PowerPoint
Input BMW	PDF, Word, PowerPoint
Team material & organisation	PDF, Word, PowerPoint, Excel
Process documentation	Photos, Excel, Word
Analyses	PDF, Word, PowerPoint, Excel
Idea evaluation, cluster, selection	Excel
Customer feedback	Word, Excel, PowerPoint
Experiment Boards	Excel, PDF, PowerPoint
Marketing	PDF, PowerPoint, Word, Photo, Video
Lessons learned	Word, Excel
Prototypes	PDF, PowerPoint, Word, Photo, Video, CATIA, CAD
Idea description	Word, Photos, CATIA, CAD
Story board	Word, PowerPoint, PDF
Business Plan	Word, PDF
Interviews	Word
Hypothesis	Word, PowerPoint, Excel
Feedback from the department	Word, PowerPoint

A critical task is to determine whether all these sources can be truly defined by the parameters selected. (The parameter selection should take into account every document generated. They ought to be general enough to cover all input sources, and specific enough to be able to describe the knowledge contained in each).

Here again it can be remarked, that the knowledge being stored in the base is mainly non-geometrical, considering a lot of different aspects of the design activities and providing tools for problem solving and decision making. (Value added in comparison to knowledge repositories, which strongly rely on geometrical data and draws, without providing context support. Recall the discussion started in chapters 2.1.1 and 4.1).

4. ***Seek for potentially reusable ontologies***
   No past ontologies were found that could satisfy the requirements set in terms of the knowledge base and the concrete project needs.

5. ***Develop a taxonomy***
   After having studied all the documents, the next task is to order all their inputs in a logical structure. This structure should be general enough to allow the introduction of new documents which weren't considered when developing the ontology design.
   In the case of this project, the taxonomy has been organized in three main structures to contain the documents. The allocation of the documents along these hierarchies will allow finding the desired knowledge, establishing relationships between documents and phases providing added value to the end-user.

   This three hierarchies aim to embrace all the knowledge generated by means of the ramification of the three principal concepts into more specific branches.

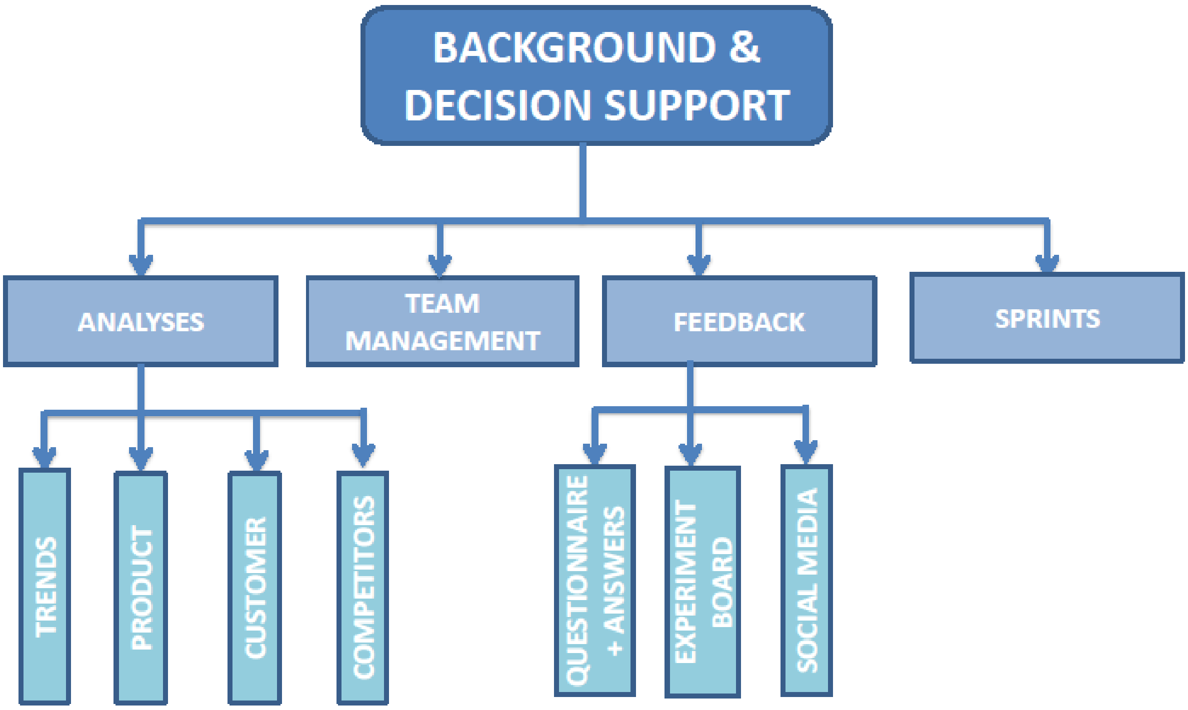


Figure 4-4: Knowledge structuration. Background & decision support hierarchy

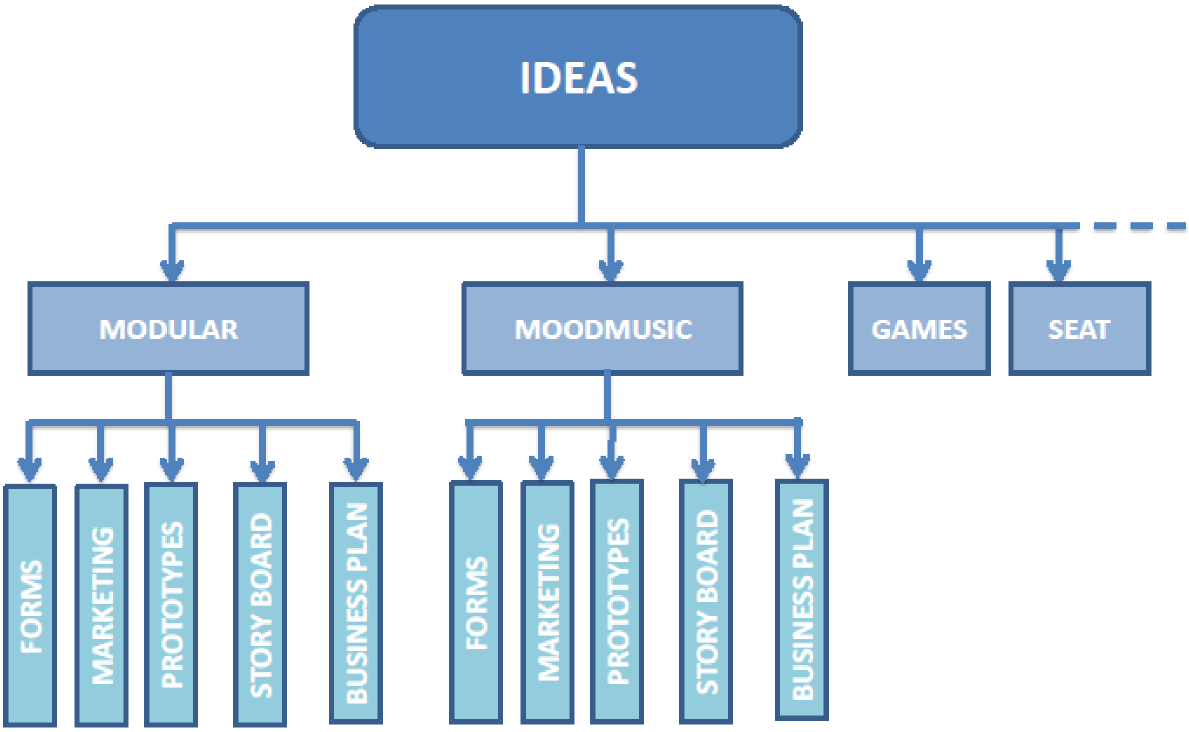


Figure 4-5: Knowledge structuration. Ideas hierarchy

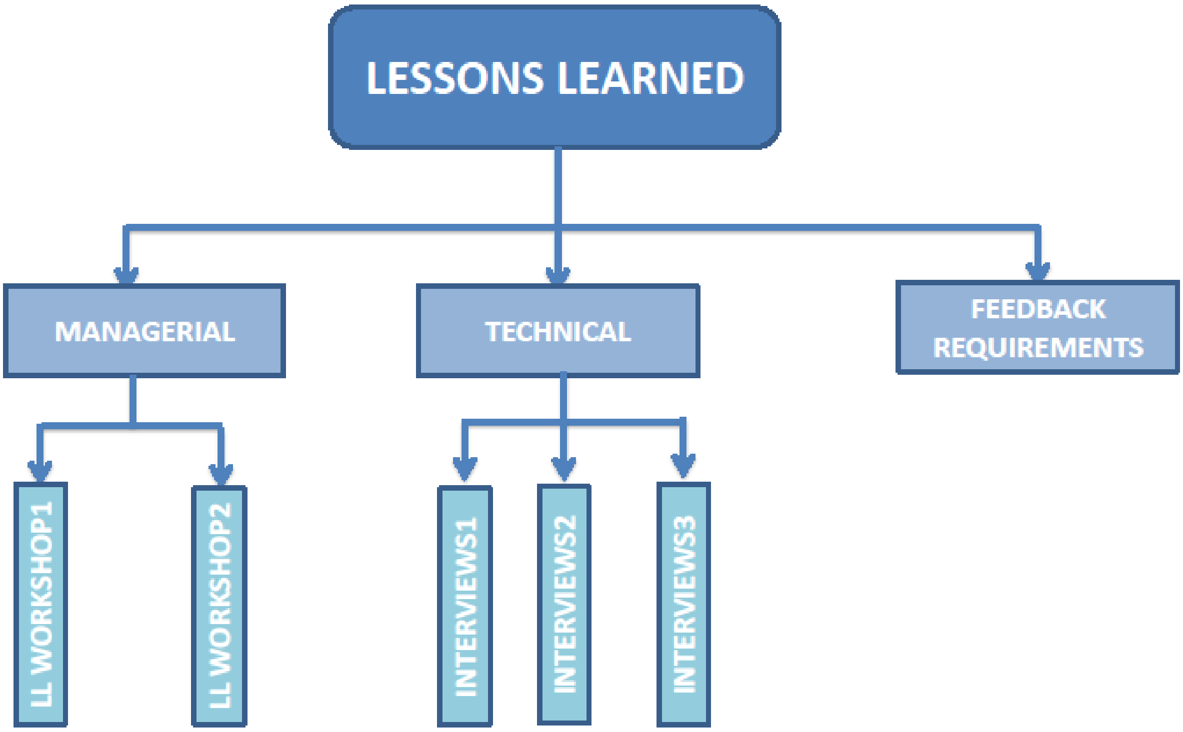


Figure 4-6: Knowledge structuration. Lessons Learned hierarchy

These hierarchies allow representing different kind of nodes attending to the level of abstraction, going from "concept" to "category", from "category" to "subcategory" and from "subcategory" to "documents". This way, a representation according to the content to be found attending to the branches selected, can be visualized.
It is understandable, that the relationships are not unique and that some documents may belong to more than one field. Moreover, there might also be generic documents (competitors' analysis for example), that even when they are not result of the development of an idea, they are closely related to its evolution. Therefore, the field "idea related" was created and to support this interconnection of documents and hierarchies, also the field "subcategory related" was introduced. (The introduction of these two fields allow not only the visual connection of these items, but also these documents to be found buy the searching engine, when entering the specific parameter in the base. So to say, more keywords are being assigned to the concrete document).
The visualization and organisation of the ontology be means of these three structures, is the responsibility of the attributes of the metadata: Concept, category, subcategory, idea related and subcategory related. Thanks to the metadata, by introducing these parameters, the structures will be depicted and the documents correspondingly ordered.

Lastly, to round the taxonomy and provide not only with a further visualisation tool but also with a different perspective to face the search, a time frame was also designed. This feature is very useful, as it does not only speed the search process and target more specific knowledge, but it can also represent a clear image of the product development and the remaining development expenses. This timeframe representation is the responsible of the attributes phase and sub-phase of the metadata. Entering these values will automatically establish the relationships between documents and stages.

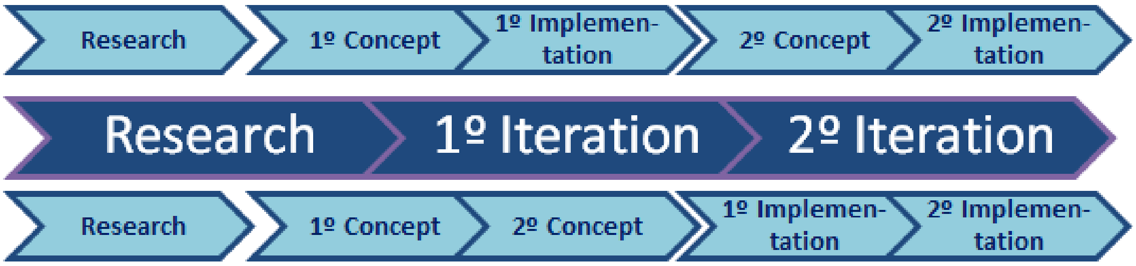


Figure 4-7: Knowledge structuration. Timeframe - Composition of the global project phases and the ideas development phases

The remaining attribute of the metadata, "status", is defined, so that the knowledge base fulfils the Lauer's (2010) parameters and the MyMINI team expectations. It aims to help defining the concretisation level and speed the search, allowing the user to go for the last version of the documents.

The steps 6 to 8 of the ontology creation process will be developed in the following chapters.

6. ***Add the relationships and connections between elements***
7. ***Evaluation***
8. ***Manage the organizational maintainance***

4.4 Definition of the connections

To give shape to the ontology and establish the interconnections between hierarchies, the design of links is needed. This is the sixth step we mentioned before (***6. Add the relationships and connections between elements***). In the case of our knowledge base, three different types of linkages were generated.

The first type of linkage supports the hierarchical structure. These connections are called in Soley (our visualization tool) "contains" connection. These relationships build the hierarchical trees. The second type of linkages, relate the different documents to their corresponding category or subcategory. (At least one linkage but depending on the document it might have more). These connections are of the class "belong". The last type of connection is the one linking the documents to the timeline. These relationships are called in the implementation "is".

Having different type of linkages allows the searcher to use different representation views and get a more specific and detailed filtering tool. Moreover, the number of incoming connections to a document will also give an image of the generality and specificity of a document, also allowing speeding the search attending to these characterisations.

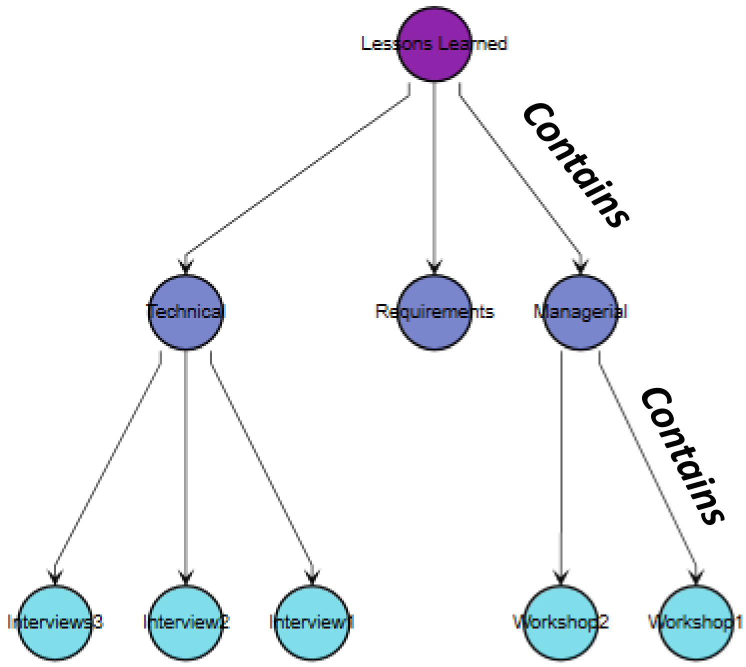


Figure 4-8: Example of "contains" linkage

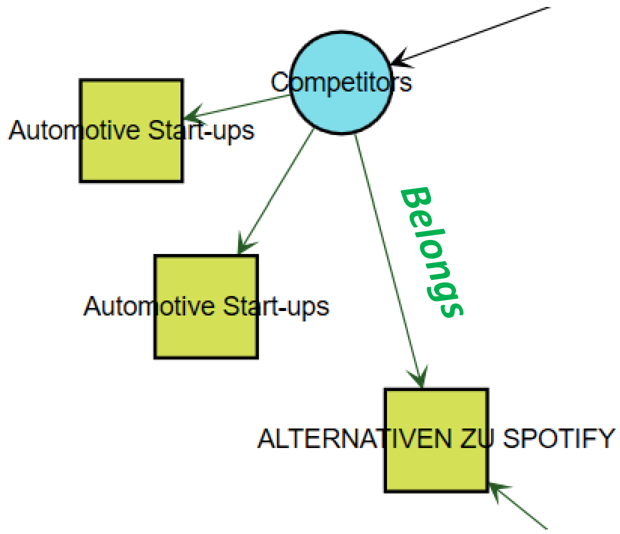


Figure 4-9: Example of "belongs" linkage

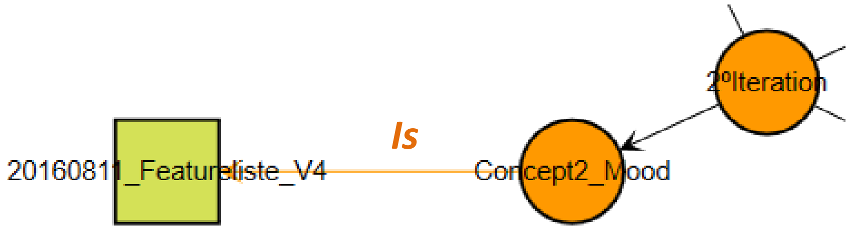


Figure 4-10: Example of "is" linkage

4.5 Analysis of the complete design

In this chapter the seventh step will be approached (***7. Evaluation***). The intention is to prove, that all the metadata, ontology and connections introduced in the previous paragraphs, successfully cover all the requirements set. Hence, to check if the fourteen identified requirements have been accomplished.
To do so, both literature and user's feedback have to be taken into account. In this chapter, some literature statements will support the goal achieving, whereas chapter number 7 will approach the user's-centred part.

To begin with, let's recall that this base differs from the several data-information repositories, because it mainly focuses in knowledge (generally avoiding data and information). This is achieved, as designers limit the documentation stored, to the important knowledge and main information supporting the idea creation and the reasoning behind the decisions taken.

Now is time to evaluate if the attributes that Lauer (2010) considered to be necessary to describe documents and processes (chapter 2.2.4) are addressed. Then it will be explained, how each of these description parameters (Table 4-3) can be found in the knowledge base of this thesis.

Table 4-3: Composition of the describing parameters for documents and processes 2 (Translation of Lauer 2010)

Nr.	Description parameter	Document characteristics	Process characteristics
1	Content	Content	Work-content
2	Concretization degree	Concretization degree, phase location	Process phases
3	Remaining development expenses	Remaining development expenses	No directly comparable feature available
4	Usage	Purpose in the product development process	Purpose/Goal
5	Networking degree	Comprehensibility, extension	Complexity degree

The field ***content (1)*** is covered by the introduction of the three hierarchical structures which attend to the knowledge contained in every document. Also the name and description attributes of the metadata, help identifying the knowledge enclosed in a document. The ***concretization degree (2)*** can be measured with the help of the status attribute which distinguish between and ended document and its previous (non-ended) versions. The ***remaining development expenses (3)*** are represented thanks to the timeline where the product evolution can be measured according to the project phases. Also the registration date can be used as a filtering attribute for this purpose. More specifically, the Sprint document contains the exact percentage estimation of the idea development. The ***usage or purpose (4)*** of the document doesn't have a specific attribute to be defined, nevertheless for the objectives of this thesis; it will be considered that the goals of looking for a given knowledge are to innovate or to improve an existent solution. Hence, to activate this filter a combination of the attributes phase/sub-phase and status can be used. It is commonly understood, that in order not to kill creativity, to innovate, only the knowledge generated in the first phases should be seen (as well as avoiding the last version of the documents is recommended). (Morales Quiles 2016). Regarding the ***complexity degree (5)*** of the documents, it will be assumed that in a student project, all documents contain a similar complexity level. The distinction will only be done attending to the generality or specificity of the documents, considering that the specific documents are the ones having a higher complexity level.

Now that the attributes to describe a document have been compared with the ones established by Lauer (2010), the same must be done with the list of requirements set for the knowledge basis of this work. Nonetheless, this evaluation requires user's feedback regarding the implementation of the base and the results obtained from its use. Its approach and measurement will be done in chapter 7 with the help of eight volunteers, who will commit two searches attending to two different case studies. These cases, based on typical design situations, will be each bounded to a different searching tool. This evaluation methodology will allow analysing and measuring diverse factors, furthermore the approach and consecution of the requirements set.

Table 4-4: Recapitulation of the fourteen requirements for this knowledge base

Nr.	Requirement	Nr.	Requirement
1	Adjusted to demand	8	The search function must be supported
2	Process oriented	9	Usefulness for as many end-users as possible
3	Across phases + Time frame	10	Visual structure with multiple representations
4	Across levels	11	All terms and type of relationships must be distinguishable and properly explained in a legend
5	Different perspectives	12	Need of keeping it updated
6	Simplicity in its use	13	Fast to register and use knowledge
7	Added value must be perceptible	14	Flexible to allow development iterations

The last step of the model ***(8. Manage the organizational maintenance)*** escapes the control of the knowledge base designer. Nevertheless, the rapid and simple access to the knowledge, the easiness of the base operation and the characteristics of agile teams in terms of documentation (own responsibility, active documentation and actualization of the most important content, etc.) set the pillars for the knowledge base to be properly maintained and updated over the years.

4.6 Implementation of the Knowledge Base

One of the main purposes of the thesis was to implement a knowledge base to store all the documents generated during the project, attending to the requirements and challenges explained in the previous chapters. There were many features that should be taken into account and appear in the base, but the programing capabilities and the time was limited. Thus the criteria when selecting a software to implement the base, was that it should be simple to program it, but nonetheless it should provide the user with a complete experience being able to cover all the requirements set. To do so, the software picked was Soley. Soley is a software that allows visual modelling, data collection and data analysing, all with the vision of facilitating the user to manipulate complex networks and to efficiently use information.

To be able to provide the documents entering the base with the attributes already mentioned, it was needed to use the Soley Studio version (Bergen et al., 2011), so as to enter the meta-model of the software and change the available properties.

Soley works with the so called nodes. Different nodes can have different attributes according to their status. In the case of the knowledge base of this thesis, five nodes classes were designed. Concept, category, subcategory, document and event. (Figure 4-11). All five classes own the attributes: name and description. In case of the event nodes, also the attributes starting and ending date will be entered, so as to define the scope of the phases in the project evolution. In case of the document nodes, the fourteen attributes mentioned in chapter 4.2 are defined. (Name, description, size, status, type, author, registration date, concept, category, subcategory, idea related, subcategory related, phase and sub-phase).

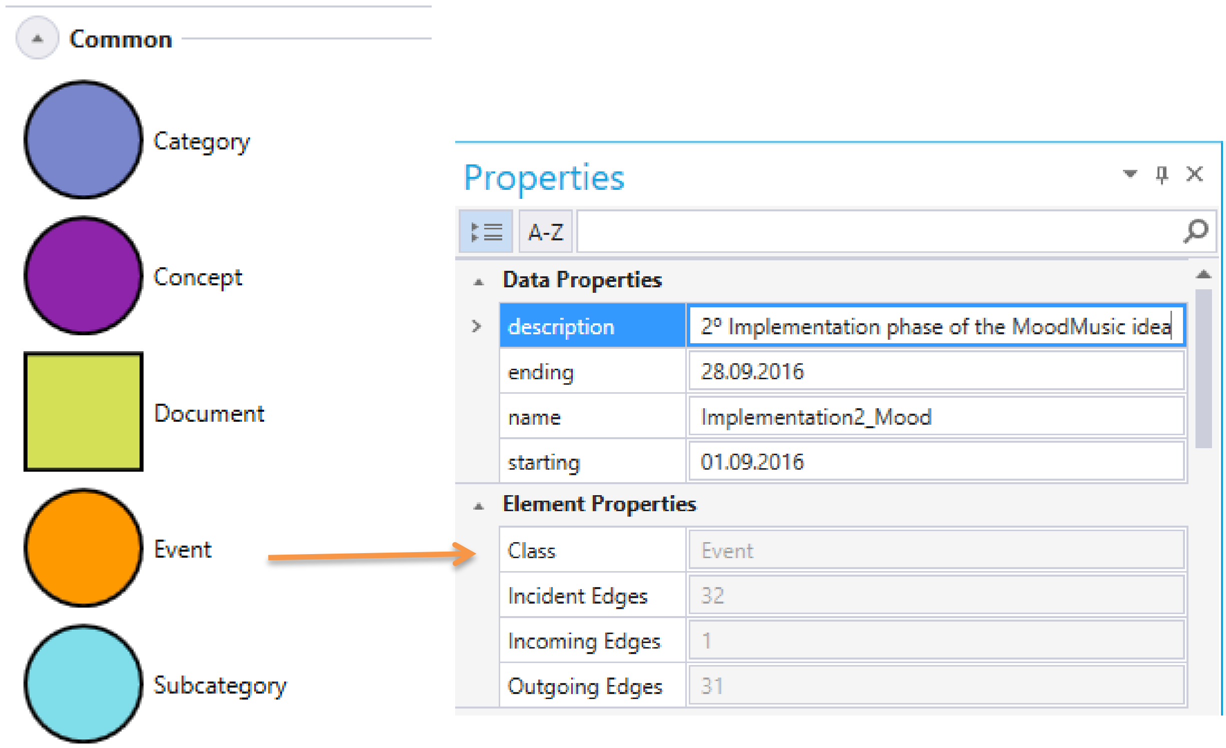


Figure 4-11: Nodes shaping the MyMINI Project knowledge base – Screenshot of a node-property window

The next step to translate our ontology into Soley Studio (Bergen et al., 2011) is to create edges. The edges give form to the hierarchies and the time frame and they also connect documents with their respective categories, subcategories or time phases. In this representation three different types of edges can be found, according to the three types of relations explained in chapter 4.4.

The first linkage type is called a "contain" relationship. This one will be employed to give shape to the hierarchies and the timeframe. Therefore, such connections will directly relate one node with their immediate superior or inferior level of abstraction of the hierarchy. They will connect all kind of nodes except from the document nodes.

The second type of connection is called "belong". This one links the documents with the hierarchies. (Document to category, subcategory or category related). One document can then have more than one incoming edge of this type.

The last type of linkage represents an "is" relationship. This edge connects every document with their correspondent phase. It represents so to say a temporal edge that supports the timeframe searching tool.

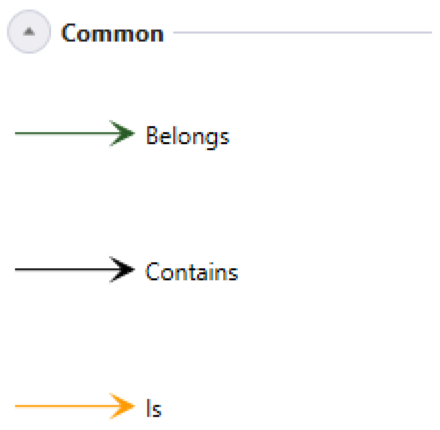


Figure 4-12: Color differentiation between edge types

Once the type nodes and edges have been defined, the hierarchical structures and the timeline can be built. From Excel all the documents with their given attributes will be imported to the model and the software will automatically establish all the relationships.

Here it can be appreciated the magnitude of the knowledge base and the amount of knowledge produced during the project.

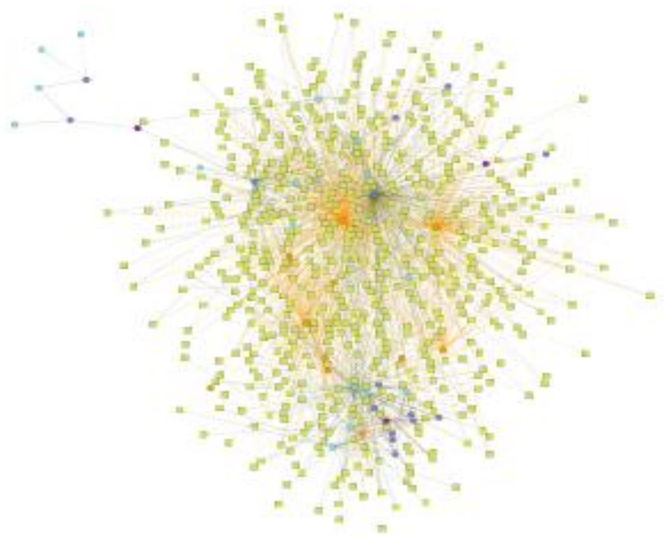


Figure 4-13: Implementation of the knowledge base in Soley. All documents, phases and connections are shown

Figure 4-14 shows one of the hierarchies in Soley. In purple the concept node, in lilac the category nodes and in blue the subcategory nodes. Please find a visualization of all three hierarchies in annex A1.

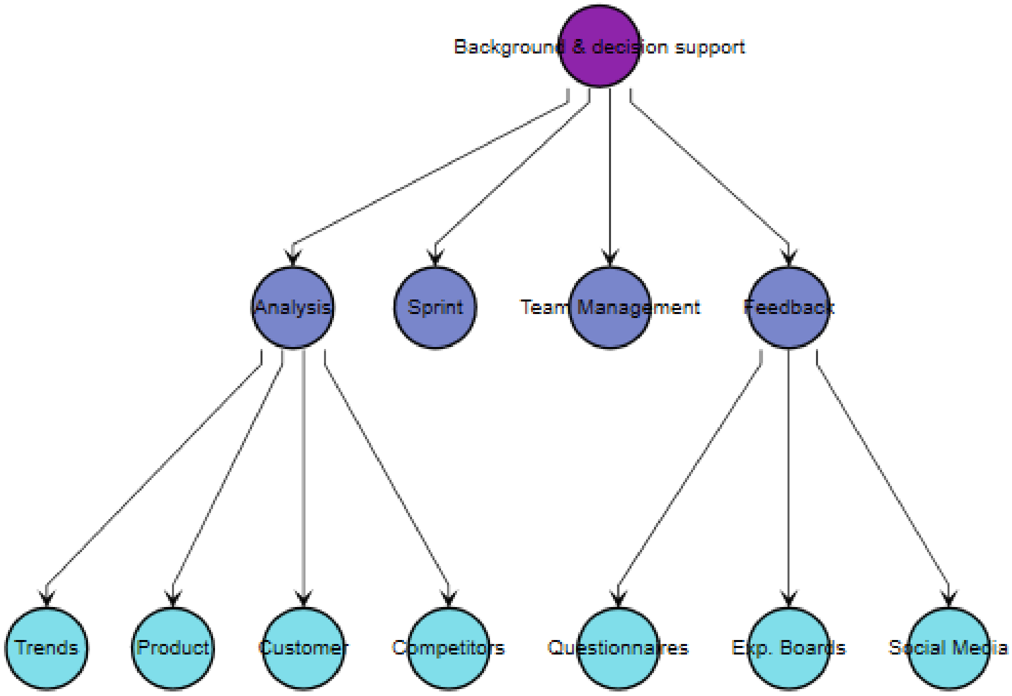


Figure 4-14: Soley hierarchical representation. Background & Decision Support hierarchy as an example

Figure 4-15 shows the Soley timeframe representation. In orange the event nodes. In the middle the main project phases and in the branches the sub-phases attending to the different two ideas carried out.

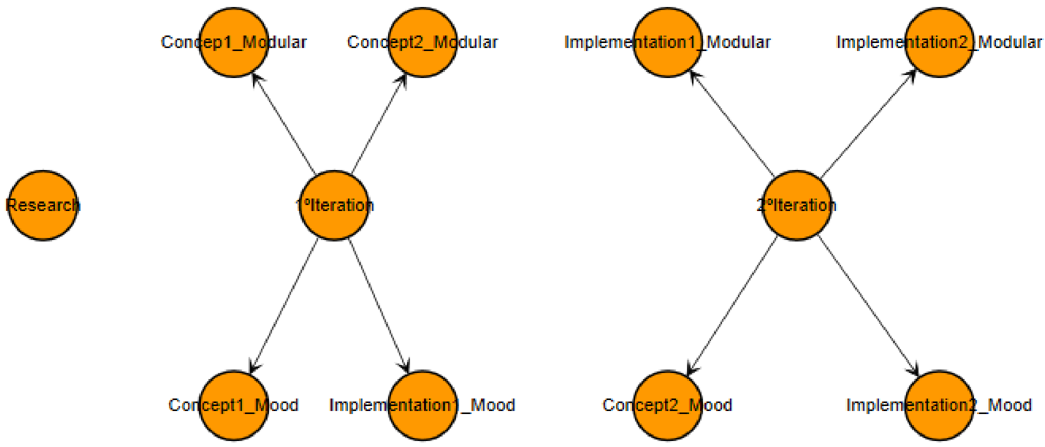


Figure 4-15: Soley representation. Timeframe

The representation of the different nodes and edges classes is eased by using different forms and colours.

Example of **category**: Managerial

Example of **concept**: Lessons Learned

Example of **document**: Results Lessons Learned 2

Example of **event**: 2º Iteration

Example of **subcategory**: Workshop2

Figure 4-16: Soley nodes legend. Colors and shapes distinction.

4.7 Examples of its use

In this chapter we will simulate a search to show some of the possibilities that the knowledge base offers.

First of all, here we have the registry document that all users introducing some document to the base will have to fulfil. It is designed to be fast and easily completed, as the users just have to write the information about the seven first fields and then mark a couple of crosses.

We will fulfil the registry document for an archive that we will afterwards look for in the base. In this concrete case it would look like this:

REGISTRATION OF A NEW DOCUMENT IN THE KNOWLEDGE BASE

Document	Name	*Fahrzeugdaten_Test_Fb*
	Description	*Poster to check the interest of MINI customers in the use of car data.*
	Size	*1.4KB*
	Status	*End*
	Type	*Powerpoint*
Registry	Related person	*Paula*
	Registration date	*10.08.2016*

Design

Concept	
Information	X
Ideas	
Lessons Learned	
Category	
Analyses	
Feedback	X
Team Management	
Sprint	
Modular	
MoodMusic	
Games	
Seat	
App	
Navi	
Coffee machine	
Shopping cart	
Managerial	
Technical	
Requirements	
Subcategory	
Trends	
Product	
Customer	
Competitors	
Questionnaires + Answers	
Exp. Board	
Social Media	X
Marketing	
Forms	
Prototypes	
Story Board	
Business Model	
LL Workshop1	
LL Workshop2	
Interviews1	
Interviews2	

Phase	
Research	
1Iteration	
2Iteration	X
Sub-Phase	
Research	
Concept1	
Concept2	X
Implementation1	
Implementation2	
Idea related	
Modular	
MoodMusic	X
Games	
Seat	
App	
Navi	
Coffee machine	
Shopping cart	
Subcategory related	
Trends	
Product	
Customer	
Competitors	
Questionnaires + Answers	
Exp. Board	
Social Media	
Marketing	X
Forms	
Prototypes	
Story Board	
Business Model	
LL Workshop1	
LL Workshop2	
Interviews1	
Interviews2	

Figure 4-17: Template to registry a new document. Registration example

Once this information is introduced in the base, the document will be created in Soley with the corresponding relationships established. When looking for the document, a window like the one shown in figure 4-18 will appear. All the information registered can be seen there. Moreover, additional information about the amount of edges entering the document or the number of neighbours has been also automatically generated and it can also be seen here.

Property window of a document node:

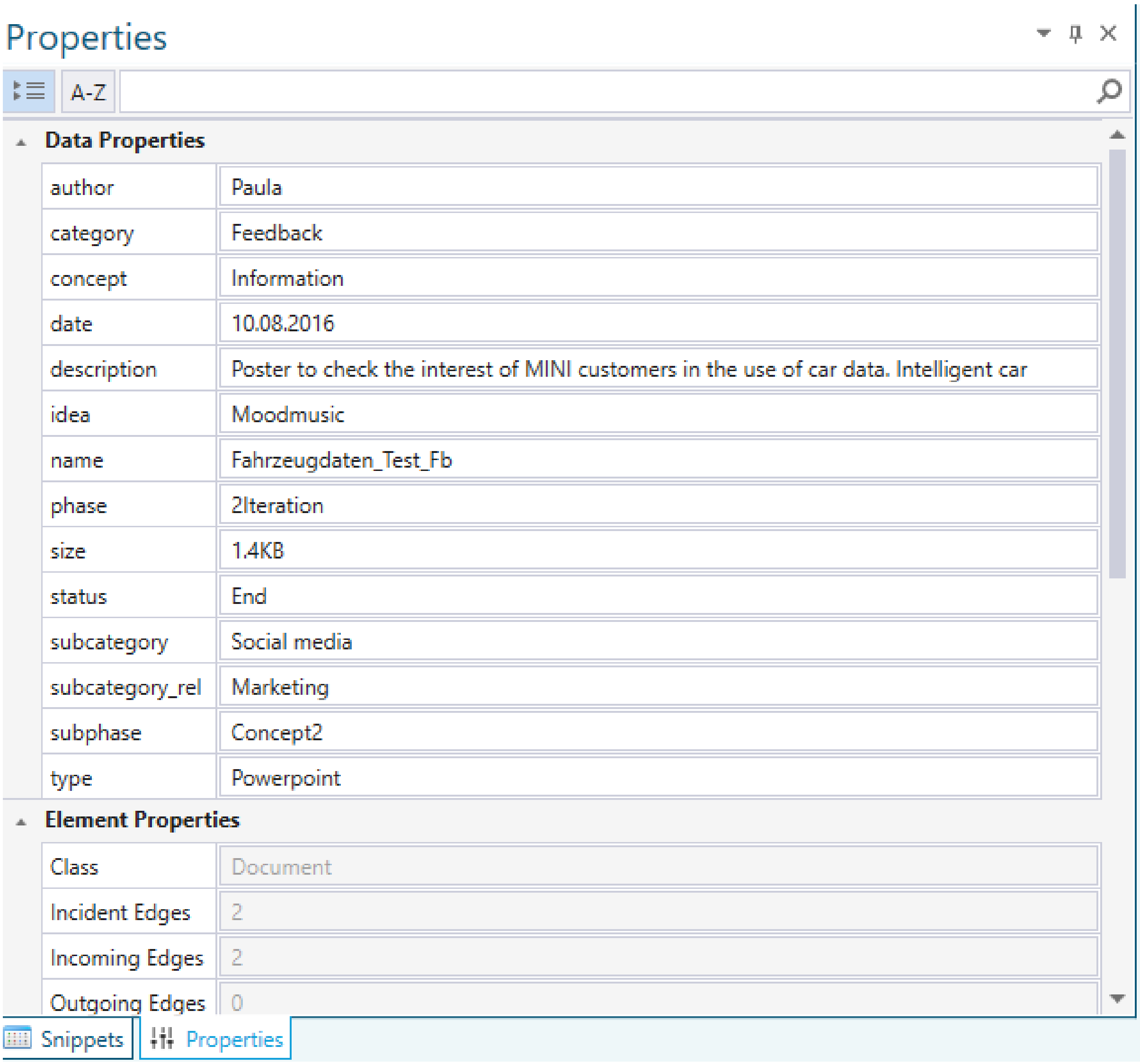


Figure 4-18: Data properties window in Soley. Document of the example

Now let´s explain what it should be done to arrive to this document from the wide pool of knowledge stored.

There are two main options to look for information in this base. On the one hand one can make use of the hierarchies or the timeframe to locate oneself in the ontology and decide where the needed information might be. On the other hand, in the knowledge base evaluation chapter, a set of rules will be presented. These help users to orient their exploration not needing to understand the structure of the base. They will just have to enter some known values of their current situation (time availability, product familiarity etc.).

In any case, these parameters will be introduced in the base by means of a filtering tool like the one shown in figure 4-19.

To find the document registered previously some of the attributes selected in the registry document were entered, and the base came out with these possibilities matching the attributes given. Our document is signalized with the blue box. More attributes could have been entered to sort out the results obtained.

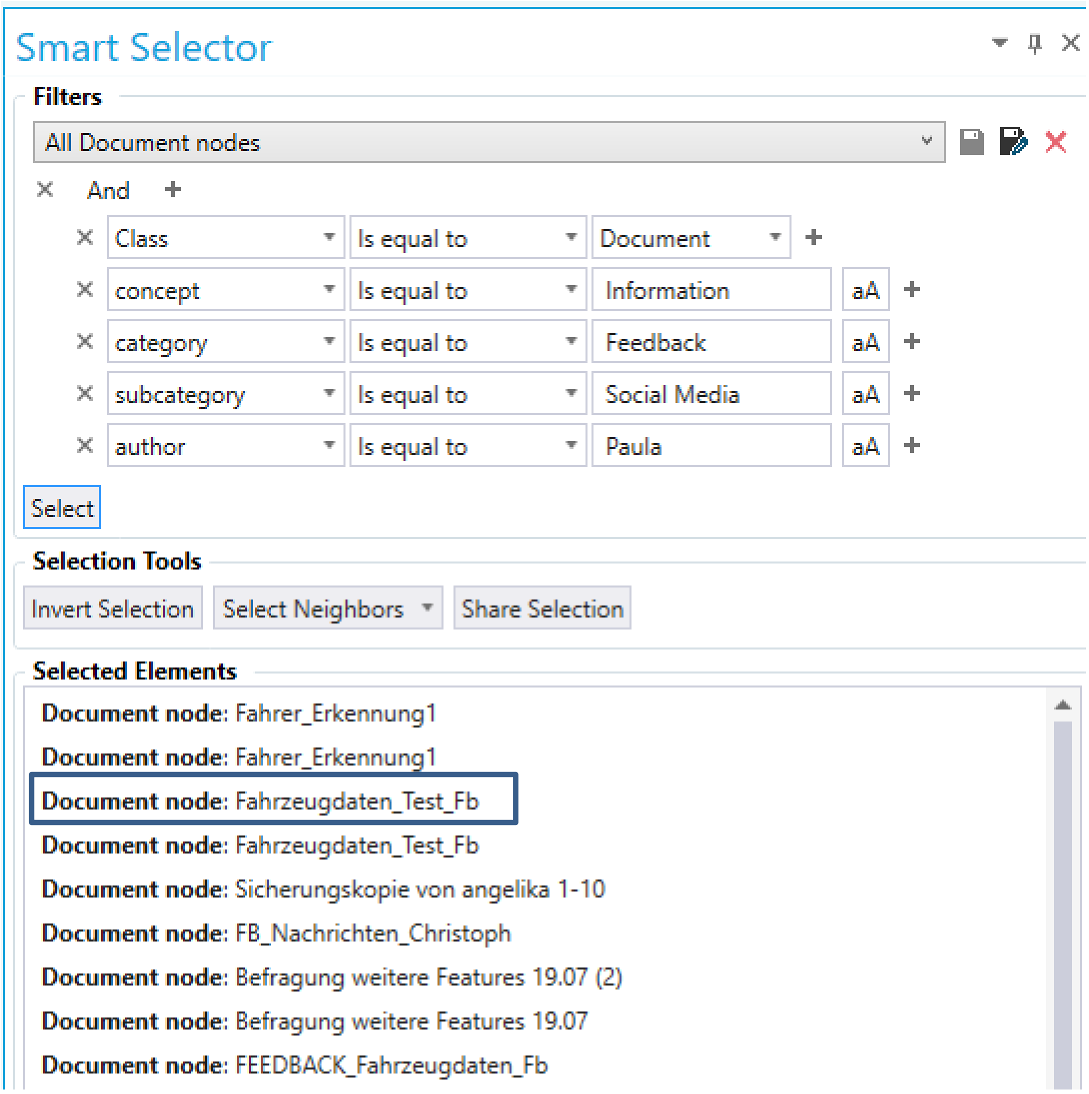


Figure 4-19: Smart selector window in Soley. Filtering tool - Example of search

5. Automatic retrieval through parameters of design situation

Through this thesis it has been stated, how beneficial knowledge reuse could be for companies in terms of time, cost and product quality efficiency. Furthermore, the little attention paid to the knowledge reuse stage when studying knowledge management processes has also been pointed out. With the aim to provide a little more light to the current investigations of the field, Morales Quiles (2016), one of the students of my tutor, devoted his work to study knowledge reuse situations and how to provide the designers in each of them with the most appropriate knowledge.

First of all it has to be made clear, what knowledge reuse situations are. Morales Quiles (2016) defines this concept as "*the context that involves a designer in his/her design place before the search and reuse of new or previous information. This knowledge reuse situation determines how knowledge or information should be given to the designer to maximize the profit that can be taken from it*." The reasoning behind this statement is that whether a company knows what the designer's needs in every situation are, the knowledge provided can be much more accurate in relevancy, type of representation, amount and timing.

To characterise these knowledge reuse situations and the factors defining or influencing them, a broad literature research was carried out. From this investigation, Morales Quiles (2016) came up with eleven parameters that he considered being the ones influencing the most the knowledge reuse situations. These are: Level of experience, familiarity with the product, type of group work, location, design phase, phase of reuse, type of activity, product complexity, purpose, status and restriction on time.

As the author intended when defining these parameters, they will be used in this thesis as a tool to provide end-users with suitable knowledge according to their knowledge reuse situation or design issue. The information provided through these parameters will be then translated into some rules that will be given to the knowledge base in form of filters, to select the relevant knowledge.

Not every defined parameter is applicable or relevant for this thesis; hence a brief analysis will be made to sort out the valid parameters to take into account when reusing the knowledge base of MyMINI Project.

Level of experience. By level of experience is understood the amount of knowledge gained through direct observation or participation in previous projects. Studies show, that the greater the amount of experience a designer has, the easiest is for him/her to learn new skills or information and to identify where past knowledge could be applied. Their capacity to use and understand different knowledge in different situations is higher. As the evaluation of the base will only be done among students, all of them unexperienced, we won't consider this parameter as relevant for our purposes.

Familiarity with the product. Knowing the product (being involved in the project) will definitely play a role when looking for information. "*Users with low domain familiarity have greater difficulty in reusing knowledge assets, due to a lack of prior knowledge that allows effective assimilation of the knowledge asset*" (Boh, 2008). This parameter will be considered in the rules as the end-users of the base will be both project insiders (familiar with the product) and outsiders. It is assumed, that when being familiar with the product one can directly look for concrete knowledge, one has the prior knowledge to simply understand visual data (not having to spend time reading big amounts of detailed text information) and one can jump to the last version of the documents.

Type of group work. Being able to change views with co-workers will affect the type of information needed. "*When you have good and daily communication with your partners, it is easier for codify (both are in the same context), save and search pass conversation or designs, which can be useful in the future. Hence, that you utilize tacit knowledge if you are near*" (Morales Quiles, 2016). Contrarily, a low communication implies generating a lot of tacit knowledge that is going to be harder to codify, share and reuse, as the context is not that well known for the rest of engineers of a company.
When using the rules, the base users will have to choose between being in a collaborative group and working independently. The literature says that in collaborative environments communication flows and in this ambient, designers prefer to work with visual data to get the information at a glance and afterwards discuss the details with their colleagues. In the other case, designers will need more detailed knowledge, as they don't have co-workers with who they could discuss the solutions.

Location. This parameter refers to the location of knowledge and their creators. It is believed that the distance between the searcher and the knowledge location influences the amount and type of knowledge required. "*Internal knowledge is more reusable that external, because is more easy to transfer and understand", "when the knowledge is internal, designers can hand out more knowledge because it is more reusable for the designer"* (Morales Quiles, 2016).
As the end-user does not know where the knowledge he/she is exactly looking for is, the location parameter will not be considered in the rules definition. (Sometimes designers do not even know what they are looking for; much less know they, where knowledge is located).

Design phase. Different project stages contain disparate knowledge, visualized in different representation ways. This distinction should be taken into account. For this rule, the user will have to select from the phases of the MyMINI Project. (Attending to different projects, the phases will vary and the knowledge contained in each too).

Phase of reuse. The knowledge to be reused depends on the three types of reuse phases (See chapter 2.3, work of Schacht & Maedche, 2016). Morales Quiles (2016) points out, that the knowledge reuse sessions taking place at the beginning of the project, generally require greater amounts of information to cover any possible problem occurring; whereas the sessions taking place during the project development will require less knowledge but more topic specific. This knowledge required varies among projects. The impossibility to generalize and the lack of a suitable parameter in our base to organize the information according to this parameter, will force us not to consider it.

Type of activity. Depending on the activity carried, the knowledge needed will be different, being its representation a critical factor to consider. Our rule will give the users the possibility to choose between an activity taking place at the beginning of the project and one at the middle-end.
The reason behind this categorisation is that the activities taking place at the star of a project tend to require more abstract, general and non-detailed information; whereas, as the project

evolves, the needs become more specialized and concrete. The work of Morales Quiles (2016) does a broader classification, by distinguishing between nine different activity types. For the purpose and scope of this thesis, the two mentioned above will be enough.

Product complexity. The product complexity covers how many levels a given product can be broken down into, so that the single designs are handy to work with. This task is completely product and company dependent. Assuming that in a student project all documents contain a similar complexity level, in this base the documents will be only distinguished attending to: general or specific. Considering the specific documents, the ones having a higher complexity level.

Purpose. The purpose of the knowledge is one of the most studied factors in knowledge reuse application, as the reuse is always done to achieve a given goal. According to the purpose of the designer the knowledge needed to be provided will vary. In our project case it makes sense to distinguish between the purposes to innovate and to improve an existing solution (Majchrzak et al. 2004). This factor is important as in innovation projects, designers should not see the finished idea, in order not to harmer their creativity. Contrarily, when improving a solution more detailed information is needed and it is worthy to go to the last project phases and last versions of the documents (Cheung et al. 2008).

Status. The status of a designer in a company can encourage the use of one information or another depending on the situation, author or source. Hierarchical barriers to knowledge access, different amount of knowledge being available or prejudices about the reuse of knowledge are covered in this factor. Designers in higher positions can access more knowledge and have more contacts to do so; nevertheless, sharing their knowledge can be perceived as losing part of their power. Contrarily designers in lower positions prefer not to reuse knowledge and strictly follow the supervisor’s orders, so that they get promoted. Also the activities of a given designer will vary according to his/her position in a company; hence the information required will also differ. Designers with a higher status address complex tasks and will go for short meetings; whereas designers with a lower status work on specialized tasks where the level of codification is high and therefore, communication via e-mail might be enough. As every user in this knowledge base environment is a student, the parameter status won't be considered. Furthermore there are no barriers to knowledge in this base, so it makes no sense to consider it.

Restriction on time. The time available to study the knowledge does have an impact in the amount and kind of information providing. Being aware of your limitations as designer in a competitive market is very important; actually it is the first step to be able to approach them in the best way possible. Therefore we will differentiate between a designer who was plenty of time to analyse the knowledge and a designer who does not. The first case is not critical, the designer can feel free to explore the knowledge base, but in the second case the last version of the documents must be provided, the visual data might help to get knowledge at a glance and going for relevant documents (those highly connected) might bring some light about the product rapidly.
(Morales Quiles, 2016).

The meaning and applicability of these rules will be translated into filter options, so the users know how their particular situation can orient the search. (Table 5-1). These rules will be used as one of the searching tools proposed when running the knowledge base evaluation. Annex A3 contains more information about the parameter analysis for the rule definition.

Table 5-1: Rules and filter parameters to support the search

EVALUATION PARAMETERS	RECOMMENDATIONS	FILTER OPTION
Familiarity with the product	**Familiar:** Jump through categories and phases to find your needs. Go for the last version of the documents. Visual documents might be enough for you. // **Not familiar:** Follow the evolution of the project through categories and phases. Explore the documents evolution and go for detailed data (text)	**Familiar:** Category=X, Phase=Y, Status=End, Type=Video/Audio/PDF/Photo
Type of group work	**Independent:** Go for detailed data (text). **//** **Collaborative:** Go for generic data (visual)	**Independent:** Type=Text/PDF/ Excel/ PowerPoint/CAD
Design Phase	Use the different **project phases** to look for the required knowledge.	Phase=X
Type of activity	**Beginning:** Abstract and undetailed knowledge is needed. Go for documents with several connections // **Middle-End:** Detailed and concrete knowledge is needed. Select the given phases and categories. Go for the last version of the documents and text formats	Nº Connections <3, Status=X, Type=Y, Category=Z, Phase=W
Product complexity	**General:** look for documents with a high number of connections or neighbours. // **Specific:** Look for documents with little or no connections.	**General vs. Specific:** Nº Connections < or > 3
Purpose	**Innovate:** Remain in the first phases in order not to harm creativity. // **Improve:** Go to the middle-last phases and final versions of the documents.	**Innovate:** Phase=Analyse, Status=In progress
Restriction on time	**Time available:** Explore the base. // **No time available:** Go for the last version of the documents and the documents with several connections (supposed to be more relevant). Visual data might be helpful to get knowledge at a glance.	**No time:** Status=End, Nº Connections > 3, Type=Video/Audio/CAD/Photo

Once the rules have been defined, this searching tool can be presented. These rules are supposed to guide the users in the search, simplifying the complexity of the network by answering a few questions. The purpose is to find the most relevant knowledge for a designer in a given knowledge reuse situation. To do so, the knowledge base user, will have to position oneself attending to the seven parameters named above. By rapidly selecting seven (or less) options from the ones proposed, the knowledge linked to the filters entered will appear. This system is thought to be fast (the end-user does not have to learn to use the base or get to know its structure) and easy to use, as the parameters to be entered regard the designer situation which should be known. The method should be especially suitable for designers who do not exactly know which knowledge they are looking for.
(More information about this searching method and the results of its application can be found in chapter 7).

6. Lessons learned sessions

Part of my role as the knowledge management expert of the team, was to be aware of the knowledge being generated and the one which was not, to try to avoid losing it. With this purpose in mind it was decided that lessons learned sessions should be run; so that the documentation of our best practices and learnings for their reuse in futures projects could be done; while improving our performance during the project life. Learning from Schacht & Maedche (2016) and the studies of multiple researches it was concluded to run two lessons learned sessions. We opted to set the first one after the first milestone, so that designers could acquaint themselves with the topic; and the second one at the end of the project, to gather the whole impressions of the project, the relevant events occurred and the evolution of the entire process. Recalling what explained in chapter 2.3, the first session will be a lessons learned session of type 2 and the last workshop will represent a lessons learned session of type 1.

6.1 Development and results of the first lessons learned workshop

Development

The first workshop took place on Friday 10.06.2016, from 10 to 12h. As the project was already initiated it was decided to carry out a lesson learned session from the second type and follow the upper cycle steps. (Recall figure 2-19).

As Schacht & Maedche (2016) did in their experiment, it was decided to do a simplification of the process, trying to give the phases more sense according to this concrete project. In figure 6-1, the phases used, its methodology and the expected results of each are represented.

During this session I personally assumed the “Lessons Learned Expert” role and the project tutor (Annette Böhmer) was the “Topic Expert”.

First of all the development of the workshop and the benefits for the team to do it were explained. It was necessary to explain some of the main topics of the workshop, such as the concepts of “Lessons Learned” and “Key Events”. Definitions and examples were both needed until the participants deeply understood the meaning of the terms and so were able to recognize them.

- “Lessons Learned” are findings, new knowledge or experiences that occur while working on a project, and its documentation. The purpose is to optimize future actions.
- “Key Events” are situations that significantly impacted the success or failure of the project.

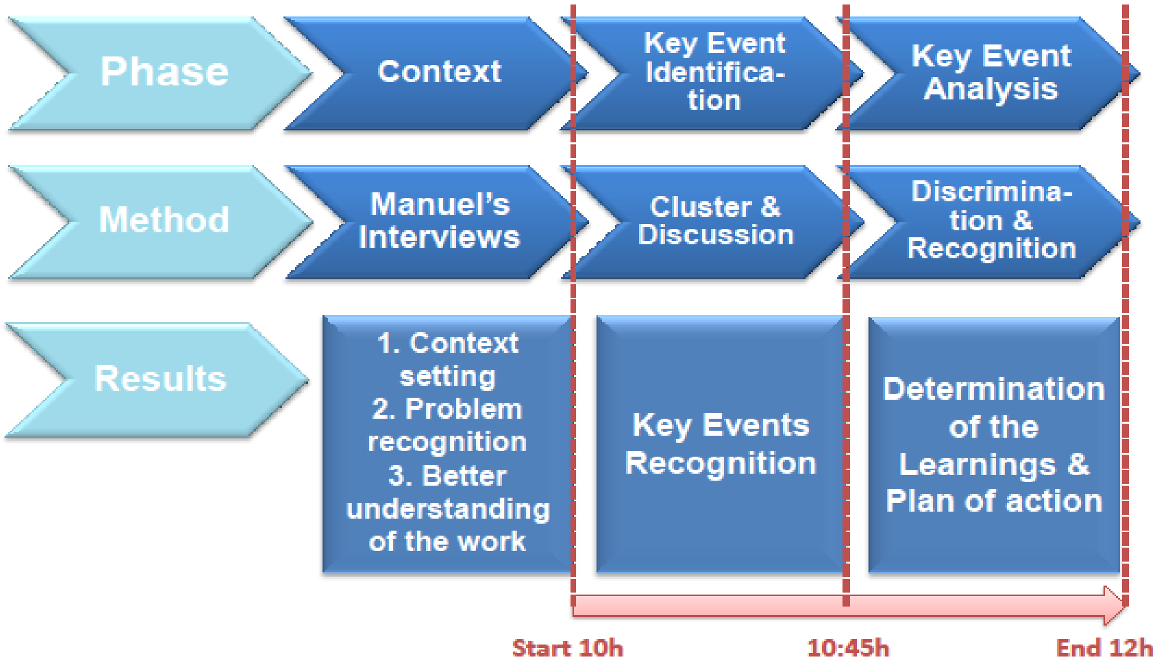


Figure 6-1: Methodology for the first lessons learned workshop

As it can be seen in the graphic of figure 6-2, all participants had a personal interview with one of my colleagues, in charge of the project documentation, with the aim of refreshing the project's context and get to know their impressions, problems and feelings about the whole. The advantage of doing personal interviews is that people use to be honest and do not change their responses according to other's opinions or group pressure.

The interview questions can be found in annex A2 (Hoehn, 2016).

Once all members went through this step, they were asked to think at home about four key points for the session.

The four questions were the following ones:

1. What do we want to reduce in our project? (Reduce)
2. What do we want to eliminate in our project? (Eliminate)
3. What do we want to increase in our project? (Increase)
4. What do we want to create in our project? (Create)

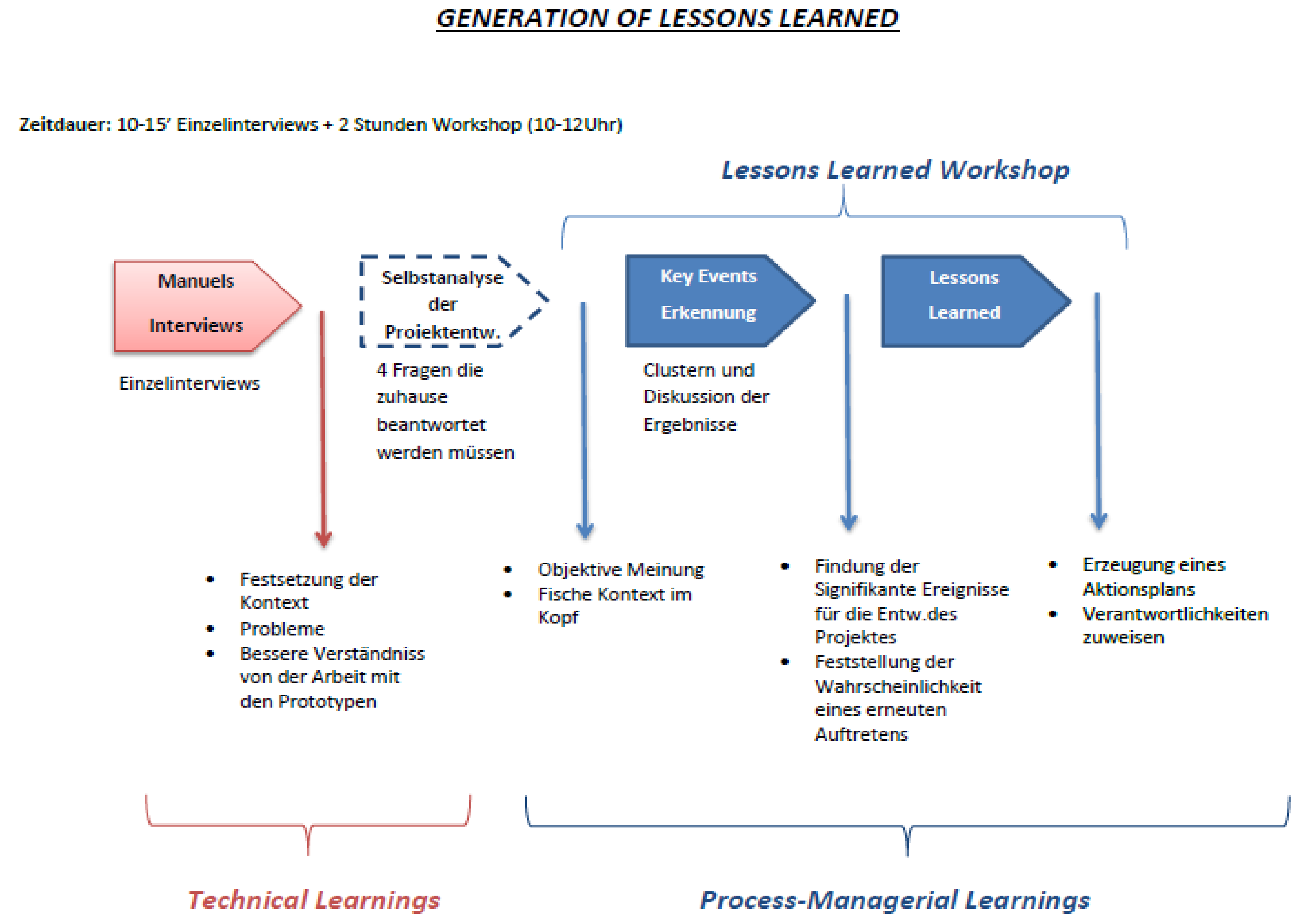


Figure 6-2: Lessons learned gathering. Managerial and technical areas

Unluckily none of the participants did that, so I gave them ten minutes to write down their thoughts at the beginning of the session.

A colour reference was established, so that the four different topics were written down on post-its of different colours. (Pink: eliminate, orange: reduce; yellow: increase, green: create). The team came up with several observations.
Once all of them were finished, we proceed to read them all and generate groups according to the content of the different post-its (until now we had not paid any attention to the colours). As expected, several results where many times repeated.
It was easy for the team to find a topic to name the different groups of information, but way more difficult was to extract the under these topics hidden, key events.
It appeared to happen, that a couple of topics contained a great amount of observations and needed more than one key event.

As said, finding the key events was not an easy task. That is why, while discussing the key events' names a lot of information about the event itself appeared (already generating some solutions and anticipating the third phase). After a while the events were collected and we could end with the second phase. It was around 11 a.m. when finished. The whole process took approximately the 45 minutes planned.

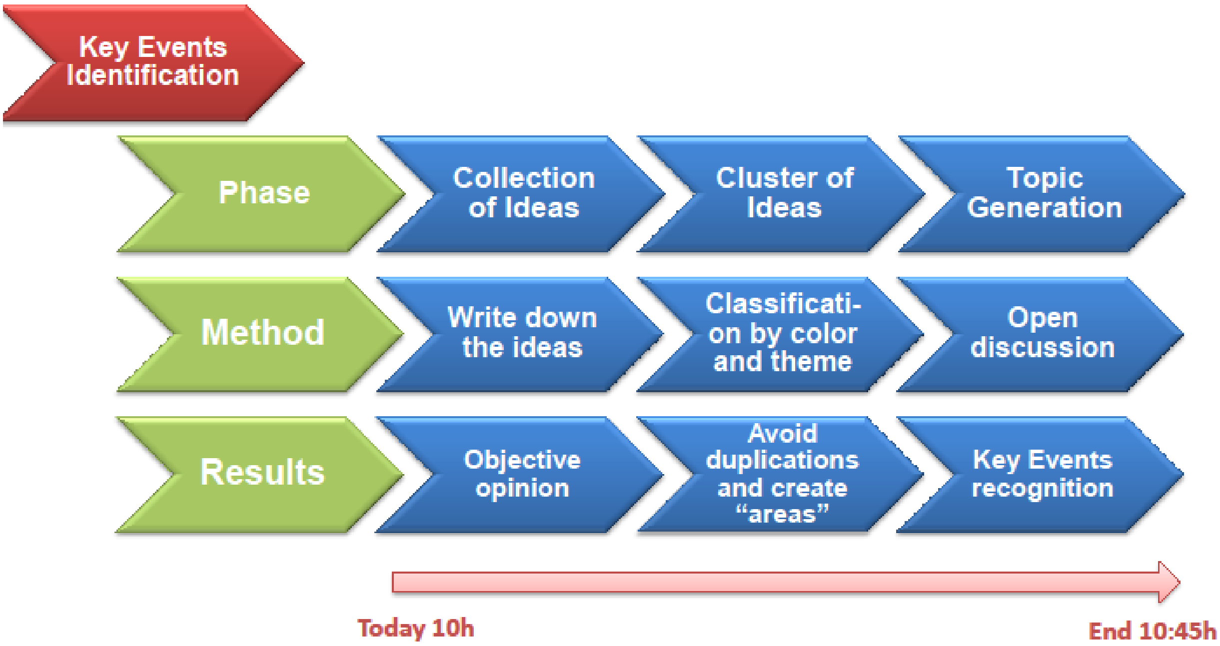


Figure 6-3: Key events identification process - 1º Lessons learned workshop

To start with the third phase, the workshop objectives were reminded again. The same was done with the concept of "lessons learned". Also the methods to be applied were explained. In our case I decided to use a combination of the methods "pass the ball" to promote interaction and "the 5-whys" to get to the bottom of the problem.
It happened to be very successful as everyone participated and the ball made the discussion

dynamic and fun. By answering the "whys" we really got to understand the cause-effect situation. Surprisingly there was not much discussion in the sense, that they mostly agreed and complemented their arguments generating new and different points of view and therefore new learnings.
First in this phase, the different colours of the post-its played a role, as we could see how positively or negatively the given events where affecting the team work.
After answering the whys, once the key event was deeply understood, the learning was generated in an open discussion, looking for everyone's agreement.

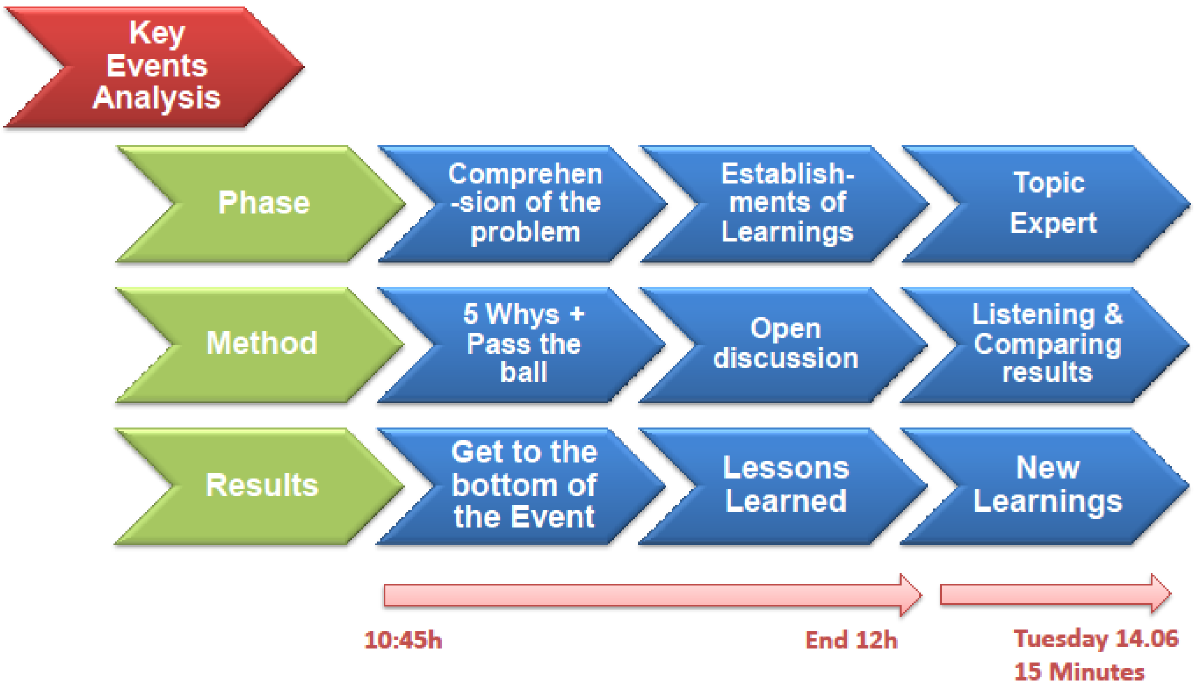


Figure 6-4: Key events analysis process - 1° Lessons learned workshop

It was very positive, that everyone was aware of the problems, the current situation of the project and their work as a team. That allowed avoiding longer (and maybe unpleasant) discussion about the causes of the key events.

Results

The next two pictures show the final boards. Here the different color posits answering the four questions are to be seen. The blue ones represent the key topics. In red are the key events identified and the big yellow notes contain the learnings. (See annexes A4 and A5).

Figure 6-5: Board with results1 - 1º Lessons learned workshop

Figure 6-6: Board with results2 - 1º Lessons learned workshop

Table 6-1 shows a recapitulation of the topics and key events discovered and their corresponding learnings.

Table 6-1: Recapitulation of the learnings - 1º Lessons learned workshop

LESSONS LEARNED WORKSHOP 10.06.2016		
TOPICS	**KEY EVENTS**	**LEARNINGS**
Decisions	Rolle allocation	Working in small teams induce productivity in the decision making process
Team-Social	Too much informal chat	The duration of the meetings should be reduced, otherwise concentration gets lost after a while
		The objectives should be set more clearly from the beginning to avoid spinning around a matter already treated
		Smartphones must be forbidden during the "jour-fix" meetings to avoid distraction and because of that the repetition of the same topics
Communi-cation	Meetings are too long	Meetings should be moderate and the activities done in a certain period of time
	Meeting-Dates must be better coordinated	“Events”-Chanel must be effectively used. Day, times of beginning and end, and meeting topic, only!
	Different expectations of different stakeholders (diffuse target)	The stakeholders must sit together and discuss their expectations and the wished result of the project. (They must prioritize their interests). The influence of the stakeholders in the project will also be prioritized
	Reliability of the team members	x
Productivity	Big teams tend to be unproductive	Working in small teams induce productivity
	Time is not efficiently used	Scrum must be recapitulated and frequently actualized to set the objectives, the things in process and the to do´s
		Everyone who comes twice late will bake a cake for the team, avoiding repetition of already discussed topics
	Smartphones cause distraction	Smartphones must be forbidden during the "jour-fix" meetings to avoid distraction and because of that the repetition of the same topics
Enthusiasm	Procedure is too traditional	Our own team-style must be found and team-logo must also be designed. So that we are strong enough as a team to follow our own inspirations and ways of proceeding, not being so much dependent on the chair procedures
	Little clarity of current steps/visualization	Organize the old ideas and old documents to make room for the new ones and this way promote creativity to do something new
		Establish a week them to bring clarity and promote result-oriented work

Ideas	Subjectivity in the select ion of ideas	Work subjectivity has pushed the motivation of the team members. As the ideas will be approved/disapproved by the customers, we will only continue working on the good ideas, from the ones that motivated the workers. Win-Win situation

During the development of the session, the topic expert was not able to be present and therefore we got her opinion and advices about our findings a couple of days afterwards. Our topic expert was Annette, our tutor and main stakeholder. She was chosen as our expert because she has experience dealing with construction projects and she knows the team and the way it works. Therefore it would be easier for her to recognize our weaknesses and find out areas to be improved.

In this particular case, as the topic expert was very project-related, her absence allowed the team members to speak freely and honestly.

On Tuesday 22.06.2016 she visited us and went through every of our findings. She agreed with everything and made very wise and interesting comments based on her previous experiences. Some of the themes already worked in the workshop were briefly commented again and she introduced a couple of new topics to be discussed.

From her remarks we could expand our learnings with the following feedbacks:

- The team should create their own vision, mission and logo, to stablish their own style and be more confident about their ideas and decisions. This should help them to work straight forward and not be "manipulated" or that much influenced from the different stakeholders.
- A tool must be continuously used (Scrum). This should help to solve the lack of clarity regarding objectives, deadlines and future steps. Every team member has to actively participate in the development of the board. This is not supposed to be the task of the leader.
- To avoid long discussions and the repetition of topics, are measures like smartphones prohibition, shorter meetings, and the use of an agenda plus planning time schedules, effective. To work in smaller teams will also facilitate productivity and less communication expenses.

This way, understanding and summarizing both the learnings of the team and the ones of the topic expert, we got to document the following list of lessons learned.

Results - 1º Lessons Learned Session:

1.- Work in small teams

Working all together led to very time consuming decision making processes and unproductivity.

2.- The duration of the meetings will be reduced

The team members lost concentration and started informal chats, forgetting this way the purpose of the meeting. (Unproductivity)

3.- The objectives of the meetings will be clearly defined

The team members didn’t know the purpose of the meetings and tended to discuss about other themes which didn’t correspond or were irrelevant.

4.- The meetings will be moderated

Meetings were too long. One explanation is that the different themes were discussed too long because there was no fixed agenda to be followed.

5.- The “Events”-Channel will be effectively used

The appointments used to be communicated in the general group. That led to confusions or were not read.

6.- Prioritizing of the stakeholders will be done

The different opinions of the several stakeholders caused confusion and misunderstandings.

7.- Scrum will be recapitulated and extensively used (keep loyal to this tool)

The team was being unproductive, the roles and tasks were not clearly defined and assigned. Focus got lost and the next steps were unclear.

8.- A cake will be baked when coming late twice

Unpunctuality led to the repetition of discussions and some people weren’t aware of the project updates.

9.- Smartphones will be forbidden during the "jour-fix"

Distraction during the meetings caused the repetition of the same topics.

10.- Team identification must be found. Vision/Mission/Logo

It was difficult for the group to keep in mind what for an objective they had and who they were as team. (Problem with their role between the several stakeholders)

11.- Organize and make room for the new ideas

Due to the lack of space the generation of new ideas and the visualization of the latest progresses were only possible to a limited extent.

12.- Establish a Week-Theme (NOT DONE)

To help clarifying objectives and task allocation

13.- Continue working subjective

The team members develop the ideas that they like. The combination of being motivated to work on an idea while keeping client oriented has led to very good results.

14.- Continue with the creative sessions

The team has come up with very good ideas thanks to their creative sessions, brainstorming’s and other creativity methods.

15.- Rolle definition

Having clear objectives (roles) will allow the team to speed their work packages distribution and become “experts” of a given topic; being so able to respond rapidly to changes/needs.

This list is stored as a word document in the base. According to the Lessons Learned hierarchy, it can be found under the category: managerial, subcategory: first workshop. The same is applicable for the video file of the session and the excel document with the learnings.

6.2 Development and results of the second lessons learned workshop

Development

This second workshop occurred on Tuesday the twentieth of September. It corresponds to a lesson learned session of type 1 or so called post project-mortem session. The development of this workshop was controversial. Schacht & Maedche (2016), the authors on which the previous workshop was based, do not even consider this type of sessions in their work. They claim that such sessions have the lowest impact in knowledge reuse and that they are a source of blaming, where failures and causes tend not to be recognised.
Nevertheless, there are some authors who offer different points of view regarding this kind of sessions. A couple of examples are the quote of *Von Zedtwitz 2002* "Post-project reviews are one opportunity to systematically improve performance in subsequent projects'' or the studies of *Busby 1999.* This last one states that people do not always learn automatically from their professional experiences, so the learning exercise needs to be prompted and structured to be meaningful and useful to most people. Moreover the global knowledge acquired from a project is dispersed among several people and it needs to be collected to posteriorly be disseminated within the organisation and so avoid repeating mistakes.
In order not to lose the opportunity to gather some more learnings that could be useful for future projects, it was decided to run the session.

The literature research reported that post-project sessions use to follow the so called *Maturity Model*. This model is organized in five levels, being these called: Initiating process, planning process, executing process, controlling and closeout process (White & Cohan 2010).

The missions of each level are the following:

1. **Define the project:** It is important to establish the specific need and purpose of the lessons, and which individuals should comprise the project team. (Staff selection according to expertise).
2. **Collect:** Capture of information through structured and unstructured processes.
3. **Verify and synthesize:** Verify the accuracy and determine, whether the learning is generally applicable or specific.
4. **Store:** Knowledge base - Allows users to identify and search lessons by keyword.
5. **Disseminate:** To benefit from the learnings they must be disseminate. Push/Pull strategies.

Regarding the lessons learned session, only the three first levels are relevant.
Approaching the first one, the information that we mainly aim to obtain from a post-project session can be summarized in four questions.

1. *What went well?*
2. *What didn't go well or had unintended consequences?*
3. *If you had it all to do over again, what would you do differently?*
4. *What recommendations would you make to others doing similar projects?*

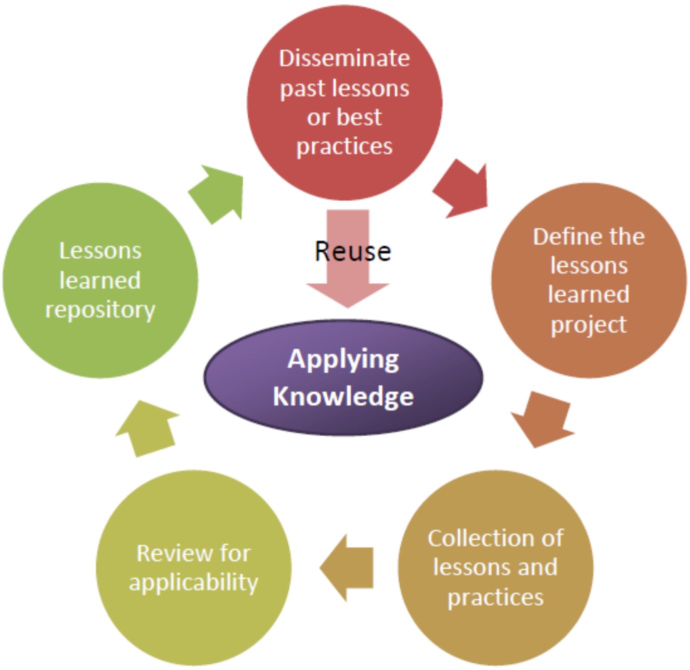


Figure 6-7: The five levels of the Maturity Model (White & Cohan 2010)

Collier et al. (1996) also agree with the four areas of knowledge to be obtained and goes further proposing a methodology to achieve what they call, the “aha moment”. In their work they explain, that creating a timeline with all the key events occurred during the project, plus looking for the cause-effect relationships lead to the “aha moment”, meaning with this a full understanding of how the project evolved and why the different situations happened and how to foster or eliminate them in future projects.

Regarding the documentation of the session, they suggest describing the project context and recapitulating the three best factors that played a role to achieve the goal, the three worst ones that obstructed it and what they call “the ugly”, meaning all immediate improvements for future projects. (Issues that ought to be changed in the next starting project). Recalling the negativism of the results of the last workshop, I found it very interesting to force the members to come with at least three positive factors which had positively influenced the project.

In order to keep analogy with the last session, to run this one, a combination of Schacht methodology and the Maturity Model will be carried out. To begin with, an adaptation of the Schacht’s cycle was needed. To do so we will consider the main steps of the cycles and incorporate to them the new objectives.

Additionally a couple of factors had to be taken into account. Unlike the first session, in this one the project was already closed. That means that the team is not trying to look for solutions and helpful advice for their own performance, but for the one of future projects. Moreover, in this concrete case the team had worked in two different sub-teams, who didn't almost share any information between them. Also to keep in mind is the point that lessons learned had already been extracted in the last session. To check if they were done and whether they carried the expected impact is of great importance.
Besides, some best practices to run this type of sessions recommend focusing the workshop on behaviours and tactics and not in employees. Recalling that blaming is not the objective, rather facilitating the collective learning.

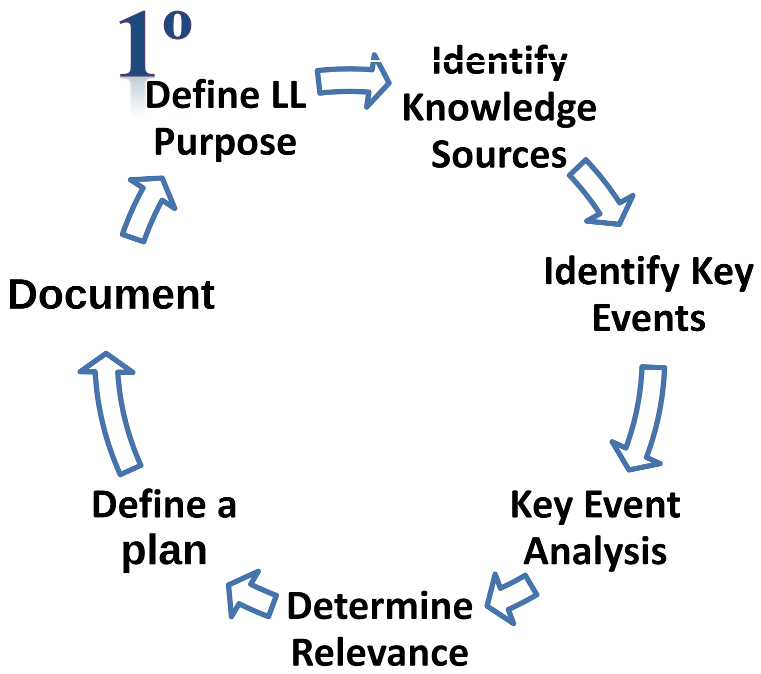


Figure 6-8: Lessons learned type 1 cycle - Adaptation of Schacht & Maedche's (2016) work

Comparing this session with the last one, I had the hope to encourage the team to come with more positive results in this one. As a member of the team, I did know, that some positive factors were not being taken into account or at least, that the negative factors were being much stronger perceived. To break this trend of only focussing on issues to improve, and so find also positive factors that the team could celebrate, (furthermore to increase their motivation and satisfaction with the work done), I decided to change the workshop development.
As can be seen in figure 6-8, the main structure is almost the same as the one used in the first workshop; but this time the way of achieving the information of every step will be modified.
To begin with, in order to refresh the context in the participant's minds and collect information about the whole project, each participant received a short questionnaire. They had to fulfil it and send it back to the lessons learned expert a couple of days before the workshop. The point was to collect project information to identify the key events causing an impact on the project. It was also interesting to get a feeling about the satisfaction of the

members with their own work and to get to know, which things they would change if they could start all over again. Sending a questionnaire allowed objectivity in the responses and the possibility for the lessons learned expert to filter and work on the results before the workshop, preparing the session according to the results obtained.

These were the questions sent to the team, whose content address the four fields from which we wanted to get knowledge in this session.

- *Were the project goals attained? If not, what changes need to be made to meet goals in the future?*
- *What surprises did the team have to deal with?*
- *What project circumstances were not anticipated?*
- *Did you develop any useful workarounds or solutions to problems that cropped up during the project? Describe it briefly.*
- *For any problems that went unresolved what preventative measures can you invent now that can help things go more smoothly next time?*
- *Are there any new "best practices" you can derive from this project? Note anything that went so well – and now seems to be so thoroughly "road tested" – that you would want to repeat the positive experience next time.*

This second workshop was also meant to least around two hours starting at 10 a.m. In figure 6-9 the development process is depictured.

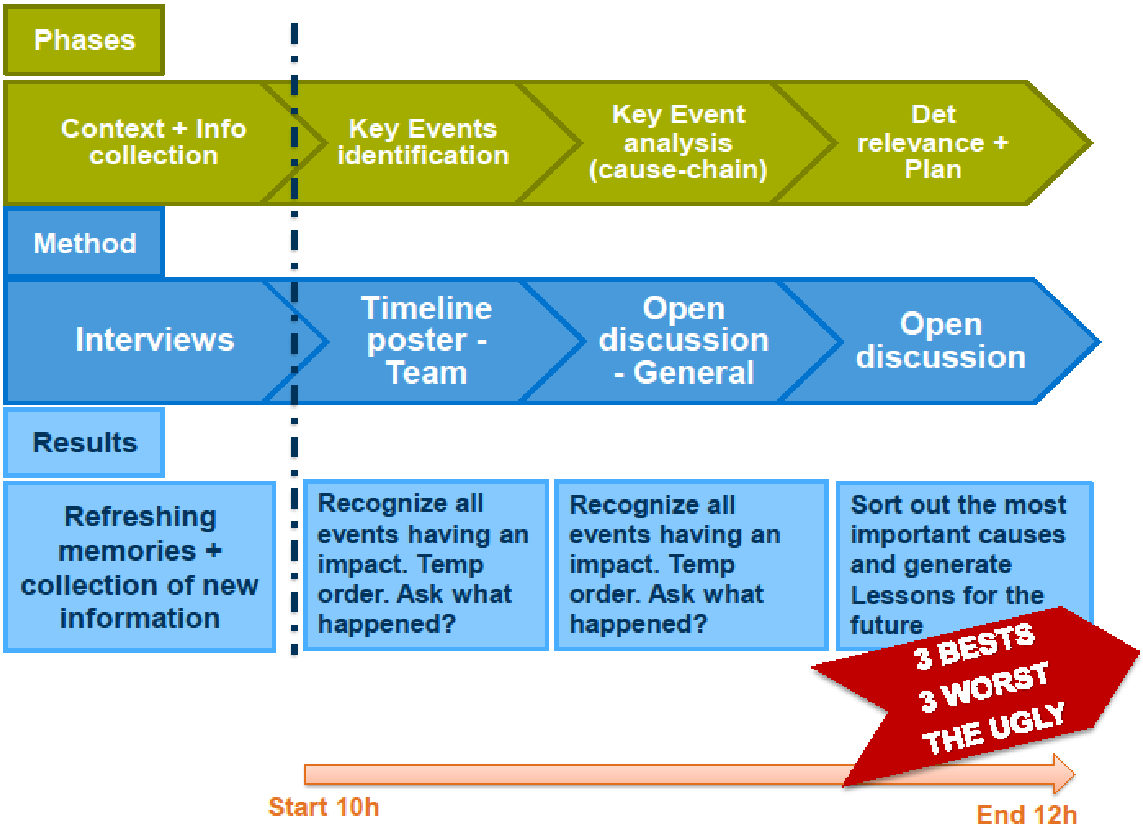


Figure 6-9: 2º Lessons learned workshop methodology

The session started by splitting the team in the two groups they had been working in and providing both of them with a timeline. In the timeline the different key events extracted from the questionnaires were represented. Some important project milestones were also part of the graphic, so that the team members could better position themselves in time.
The groups were asked to analyze their timelines and see if they could fulfil them with some more key events. Then, they were told to add to every key event, information about the cause and impact of each.

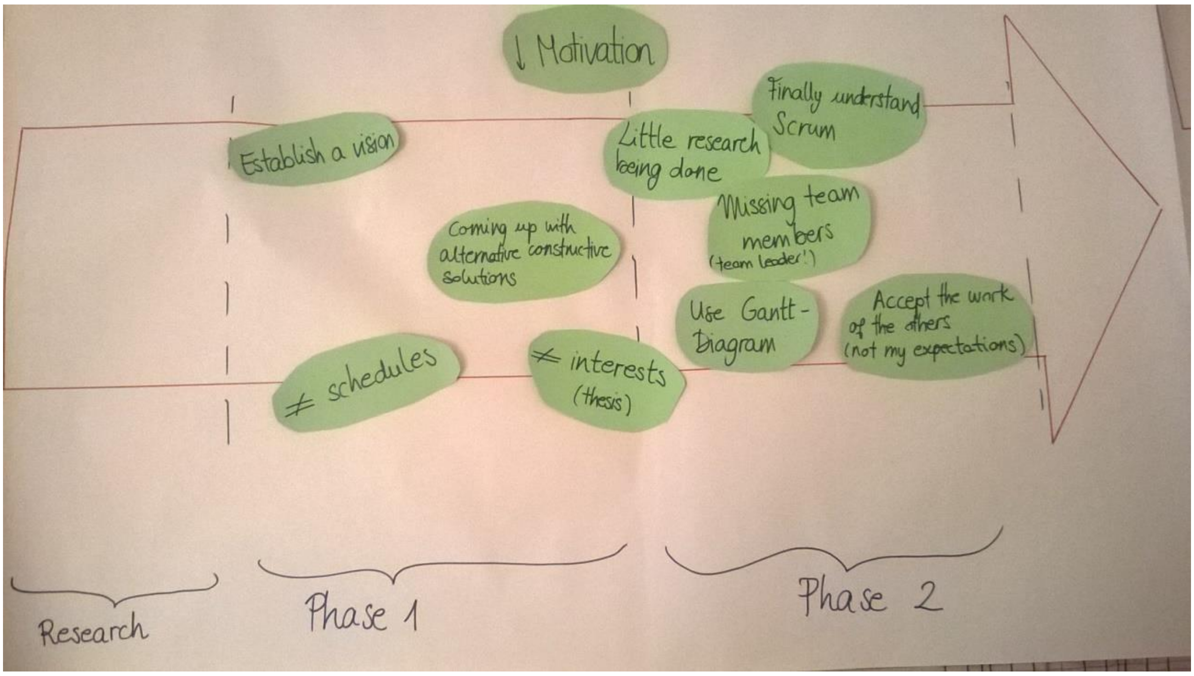


Figure 6-10: Example of a timeline - Modular idea

After twenty minutes, the groups had fulfilled their timelines and had to briefly present their results to the second team. There are two reasons behind this procedure. The first one is to generate organizational learning. As it has already been explained, the teams have worked separately and the purpose is that both of them master the knowledge generated during the project. The second reason is to generate an open discussion between teams, as often is easier to see the failures from the outside. A second perspective about their proceedings as team is always interesting and so might be the feedback that they give to each other. One again, all the members were very active in participating and showing their points of view and feelings about the different topics. It was no surprise to find out that several key events and learnings were similar or equal between teams. Mostly the ones regarding the communication with the department, the goals setting or the ones relating scrum as the working tool.

Results

Pictures 6-11 and 6-12 show the both timelines. In oval cardboards the key events are to be seen. The post-its represent the causes and effects of each of them. (See annexes A6 and A7).

Figure 6-11: Filled timeline - Modular idea

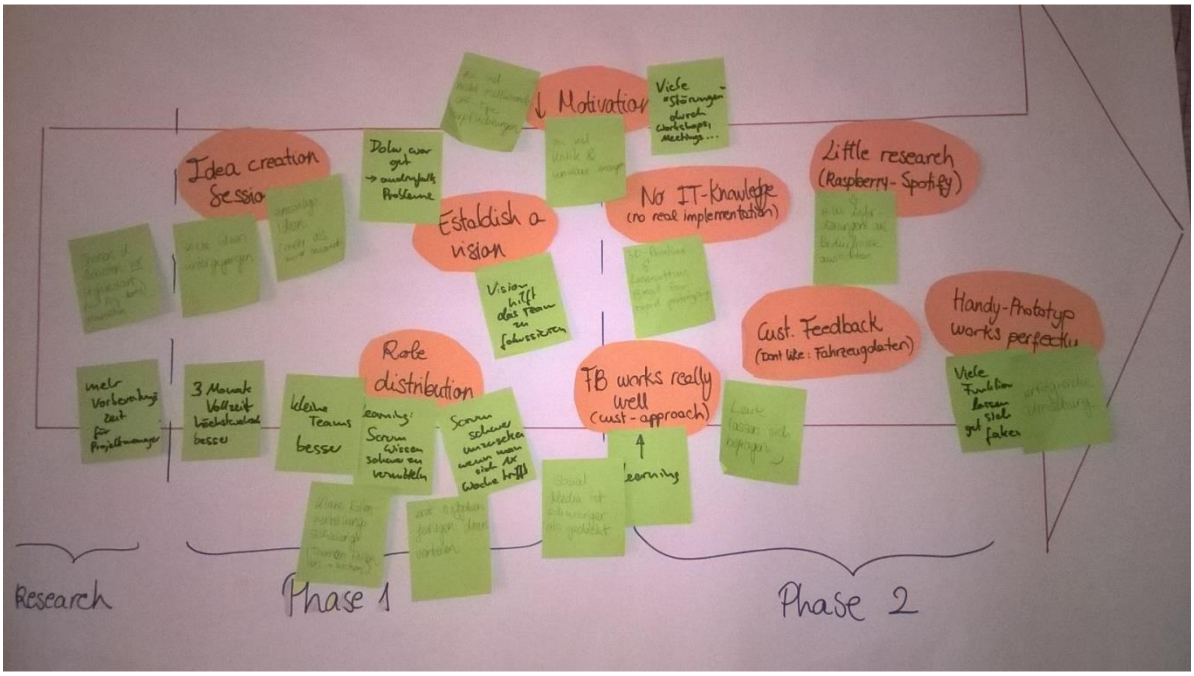


Figure 6-12: Filled timeline - MoodMusci idea

The next part of the session brought to the table the lessons learned extracted in the first workshop. We went together through each of them, starting from the accomplished ones to the not implemented ones.

Regarding the carried ones, all members agreed that their implementation was worthy and that they had simplified or improved their work (in terms of communication, productivity etc., depending on each lesson). Almost all lessons learned were successfully applied and the team members were very satisfied with their impact.

A couple of comments were done regarding the following learnings:

- ***Scrum.*** Despite the effort of the team to use scrum, there were some mismatches about the concept of scrum, its use and the way it was implemented in the team. The team had no previous experience in product development projects and that harmed the speed and agility of the tool. The project and the team work were not as intense as it should be in scrum projects, furthermore the time spent in the garage was not enough to successfully update the board and perceive the added value. Moreover the unequal motivation between members and the feeling of scrum being used as a spy tool from side of the tutors made the effects of scrum not be positively valuated.
- ***Establish a vision.*** The establishment of a vision was considered important but the mismatch with the lack of clear goals from the beginning and the uncertainty harmed its usability. Nevertheless it helped to breakdown the main idea into smaller tasks to approach the goal successfully.

Only one learning from the first workshop was not implemented:

- The ***"week-hashtag"*** was not done and the team members did not consider it worthy anymore. The division into two teams and the different activities of every team member inside the teams would have made the hashtag nonsense. Only for the initial phases would it have been worthy.

In these tables the learnings of the session are recapitulated. A distinction between the shared learnings and the team specific ones can be recognised.

Table 6-2: Learnings from Modular - 2º Lessons learned workshop

	LESSONS LEARNED	
	KEY EVENTS	**LEARNINGS**
MODULAR	Different interests and thesis topics	It is positive to have members with different motivations and interests. It has allowed to build several different prototypes
	Team members dropping out	The loss of some members led to demotivation and increased the workload of the other members
	Use of Gantt-Diagram	Once the objectives were firmly established, doing a time plan helped the team to organize the tasks according to the deadline
	Alternative constructive methods were used and new solutions discovered	Spending time in Makerspace allowed the members to get to know the constructive processes and optimize their use, coming up with clever solutions to build some special pieces
	Inner motivation + Responsibility	Despite the little support from the side of the chair, the inner motivation of this team member's was the only thing that helped them to continue developing the idea
	Trust among team members	Trusting the work performed by other members helped to speed the development process by shortening discussions and spending more time developing. Moreover the increase in trust is translated into an increase in responsibility and therefore the work quality improves

Table 6-3: Learnings from MoodMusic - 2º Lessons learned workshop

	LESSONS LEARNED	
	KEY EVENTS	**LEARNINGS**
MOODMUSIC	Lack of IT-Knowledge	It made impossible the progression of the idea in many fields. For the next time, members capabilities should be carefully evaluated
	Great responses of the customer approach methods employed (participation and valuable feedback)	Working hand in hand with customers allowed to develop a great concept. Facebook was a fantastic tool and in general customers were ready to participate and share their feedback. Their positive reaction was the most powerful driver for the team to keep developing the idea
	Great leader	Having a leader with previous experience in product development processes helped the team to follow in a structured way, by setting small goals every week that led to achieve the main objective
	Documentation	Documenting was very important to this team as it allowed them to spare time when approaching a new feature development or preparing presentations. They just had to look for the right information gathered during the previous steps. - Mostly regarding customers' feedback
	Focus on a reachable goal based in a solid vision	The team had a clear vision of their main concept and the value added for the customer of this one. This helped keeping loyal to the idea and deal with criticism, not losing track of what was meant to be conceived

Table 6-4: General learnings - 2º Lessons learned workshop

	LESSONS LEARNED	
	KEY EVENTS	LEARNINGS
WHOLE TEAM	Goals definition	The definition of the goals was done late and therefore the team's organization and outputs achieved were harmed. The amount of different stakeholders that barely talked between them and the unclear transmission of their expectation to the team, was considered to be the worst thing about the project
	Uncertainty & Demotivation	The team felt frustrated when realising that their work was not being valued and that the project tutors had a concrete expectation about the project outputs that hadn't been communicated. The impression of working for nothing ("what we do is not what they want and we realise that once the effort is done") plus being criticised, developed a general demotivation in both teams that was only partially overcome thanks to the positive customer feedback in one case and the inner-motivation of the team members in the other case. (Lack of freedom in designing. Justification of all decisions taken)
	Little communication with the department & Lessons Learned Sessions	The team felt that the communication with the chair was poor. They also found very positive the results of sitting together in the lessons learned workshops to try to improve their performance. They said that these workshops should be carried out often during the project, as they also considered that they have had a positive impact for the group dynamic and socialisation. The results should always be communicated to the department so that they can also work on the feedback given
	The project duration is too long	The team believes the work would have been much more productive if they would have concentrated their forces in a full-time 3 months project. Leaving their individual themes and other projects apart during that time, being able to work on them afterwards
	Not understanding but using Scrum	Scrum is a tool designed for designers with experience. (The team didn't know how product development procedures look like and part of the agility and speed of the tool was lost)// Scrum is suitable for intensive projects. (The team members didn't spend that much time in the garage to continuously update the board and therefore there was no added value perceived) //Scrum was seen as a spy tool. (The team used to think about what to write down and what not to, trying to fulfil the tutor expectations)// The team member's motivation level was not equal, neither was their respectively use of scrum
	Creative sessions	The creative sessions generated several interesting ideas. The methodologies employed, the use of graphic representations and coloured posits were very successful

WHOLE TEAM	Building prototypes is very helpful and time worthy	The teams realized that building prototypes help the customers to better understand the product and give much more valuable feedback. Plus the time needed is not that much and therefore worthy
	Makerspace	The team was very happy to count on this resource. The courses were fantastic and the possibility to have a "makerspace-week" brilliant. They just wished they could have completely worked there during the construction phase, as they would have taken more profit of the resources
	Social interaction among team members	Although the relationship between members was nice, this point could have been more taken into account for a better team interaction. The lessons learned sessions and team building events were considered a good tool to bring together the team members
	Too many external distractions	A lot of very different workshops had to be carried out and most of them didn't had a direct impact on the team work - they were perceived as being waste of time, bringing no benefit

The last part of the workshop had the aim to find the 3 best and worst factors, and the so called uglies. It was worthy to leave this part to the end, so the members could analyse their time in the project. First of all they worked on the timeline and generated some learnings. After that, they had the chance to recall the extracted learnings from the previous workshop and lastly it was their time to summarize all these information in the most important recommendations for the future projects.

The three considered **best factors** influencing the project were:

1. The creative sessions and idea generation methodologies.
2. The resources available such as Makerspace, the curses offered or the garage.
3. The team members. All of them very motivated, responsible, intelligent, willing to help and with social skills.

The three recognised **worst factors** influencing the achievement of the goals were:

1. The unclear definition of the goals and expectations from side of the department.
2. The size of the team. It was considered too big and therefore heavy when regarding communication and decision making fields.
3. The lack of electronic and IT competencies. This impeded the team creating better solutions as it was a handicap that they could not overcome.

The three **uglies** that immediately ought to be change in the next projects were:

1. A clear definition of the goals before the start of the project, with the consequent communication among the stakeholders of the project (tutors).
2. To separate the thesis from the project, so that the members can devote their time completely to develop ideas and spend more quality time together as team.
3. When making the next team, the competencies of the members should be carefully analysed. It would be worthy, that they own different abilities and skills so that they can complement each other.

Once again, our topic expert read the learnings a couple of days after the workshop taking place. She was amazed because of the honesty of the members and their good work breaking down the key events into very specific cause-effect relationships and learning from them. Like the last time, she gave the team a couple of insights from what she had perceived by watching the team performing. She mentioned that the garage had been misused, as the team did not work that much together; that would have helped to get into an agile flow. The Scrum Task Board was never properly used, the team adapted it to their necessities, which is not bad; but some of the benefits of using the system got lost (there was no moderation of the weekly scrum meeting and the members did not use to present their findings from the last week to the rest of the team). The vision was stablished too late (after the first lessons learned workshop) and its presence was not palpable – little impact in the daily work. Moreover, she would have wished that the team would have been more proactive asking questions to the tutors and taking profit of the monthly sessions with them. Another topic that she brought to the table was the fact that no so many prototypes were constructed. She claimed that the idea of testing every hypothesis with a prototype got lost and therefore we had to invest more time to validate the hypothesis (the prototype methodology would have been more time-efficient). Regarding the product evaluation, not all three categories were always taken into account: Usability, desirability and feasibility. From the positive side, she said that the team was brave enough to not get scared or discouraged about the numerous requirements and stakeholders and be able to find their way.

Sharing this feedback with the rest of the team, we agreed that the reason behind all this fields to be improved was the lack or poor communication between the team and the department. This uncertain environment (regarding the expectations of the department from the team, what should be accomplished? what is important to do like they want us to and where can we stablish our own working methodologies?) and first bad view exchanges with the tutors created a barrier between team and department that never got to be broken and that would have completely changed the development of the project. How to improve this point is something that according to project and team scopes will be decided in future projects. Nevertheless, it is positive to have realised that this topic should be taken into account the next time that this kind of tutor-student work takes place.

Once again the learnings of the workshop were categorised and stored in the knowledge base, to provide the next user with some advice about the issues here discussed. This time they were documented in form of an excel file and a word file. The learnings can be found under category: managerial, subcategory: second workshop.

Results - 2º Lessons Learned Session:

THE 3 BESTS

1. Creative sessions and idea generation methodologies.
2. Available resources.
3. The team members. (Motivated, responsible, intelligent, willing to help and with social skills.)

THE 3 WORSTS

1. Unclear definition of the goals and expectations.
2. Too big team. Communication and decision making were problematic.
3. Lack of electronic and IT competencies.

THE 3 UGLIES

1. Clear definition of the goals before the start of the project. Agreement between the stakeholders of the project (tutors).
2. Separate the thesis from the project.
3. Multidisciplinary team (different competencies).

Learnings of Modular

1.- Different interest have a positive impact

Having team integrands with different personal interest and thesis themes allowed to build several different prototypes attending to the individual motivations.

2.- Team members dropping out kills motivation

The loss of some members led to demotivation and increased the workload of the other members.

3.- Use of Gantt-Diagram

Once the objectives were firmly established, doing a time plan helped the team to organize the tasks according to the deadline.

4.- Use alternative constructive methods to discover new solutions

Spending time in Makerspace allowed the members to get to know the constructive processes and optimize their use, coming up with clever solutions to build some special pieces.

5.- Inner motivation and responsibility as a driver

Despite the little support from the side of the chair, the inner motivation of this team member's was the only thing that helped them to continue developing the idea.

6.- Trust among team members increases productivity

Trusting the work performed by other members helped to speed the development process by shortening discussions and spending more time developing. Moreover the increase in trust is translated into an increase in responsibility and therefore the work quality improves.

Learnings of MoodMusic

7.- Lack of IT knowledge frustrated the idea development

It made impossible the evolution of the idea in many fields. For the next time, member's capabilities should be carefully analyzed.

8.- Customer participation – A source of valuable feedback

Working hand in hand with customers allowed to develop a great concept. Facebook was a fantastic tool and in general customers were ready to participate and share their feedback. Their positive reaction was the most powerful driver for the team to keep developing the idea.

9.- An engaged leader eases the process development

Having a leader with previous experience in product development processes helped the team to follow in a structured way, by setting small goals every week that led to achieve the main objective.

10.- Findings documentation is very helpful

Documenting was very important to this team as it allowed them to spare time when approaching a new feature development or preparing presentations. They just had to look for the right information gathered during the previous steps. (Mostly regarding customer feedback)

11.- Focusing in a reachable goal and solid vision help to approach the development process and keep the motivation

The team had a clear vision of their main concept and the value added for the customer of this one. This helped keeping loyal to the idea and deal with criticism, not losing track of what was meant to be conceived.

Learnings of MyMINI team

12.- A clear goal definition is a key factor for the project success

The definition of the goals was done late and therefore the team's organization and outputs achieved were harmed. The amount of different stakeholders that barely talked between them and the unclear transmission of their expectation to the team, was considered to be the worst thing about the project.

13.- Uncertainty leads to demotivation, as the work done does not satisfy the "unknown" requirements

The team felt frustrated when realizing that their work was not being valued and that the project tutors had a concrete expectation about the project outputs that hadn't been communicated. The impression of working for nothing ("what we do is not what they want and we realize that once the effort is done") plus being criticised, developed a general demotivation in both teams that was only partially overcome thanks to the positive customer feedback in one case and the inner-motivation of the team members in the other case. (Lack of freedom in designing - Justification of all decisions taken)

14.- Little communication with the department. The tutors should also apply themselves the lessons learned gathered by the team.

The team felt that the communication with the chair was poor. They also found very positive the results of sitting together in the lessons learned workshops to try to improve their performance. They said that these workshops should be carried out often during the project, as they also considered that they have had a positive impact for the group dynamic and socialization. The results should always be communicated to the department so that they can also work on the feedback given.

15.- The project duration was too long. Lose of productivity

The team believes the work would have been much more productive if they would have concentrated their forces in a full-time three months project. Leaving their individual themes and other projects apart during that time, being able to work on them afterwards.

16.- Not understanding but using Scrum – Ineffective

(1) Scrum is a tool designed for designers with experience. (The team didn't know how product development procedures look like and part of the agility and speed of the tool was lost). (2) Scrum is suitable for intensive projects. (The team members didn't spend that much time in the garage to continuously update the board and therefore there was no added value perceived). (3) Scrum was seen as a spy tool. (The team used to think about what to write down and what not to, trying to fulfil the tutor expectations). (4) The team member's motivation level was not equal, neither was their respectively use of scrum.

17.- Creative sessions - Source of inspiration and idea generation

The creative sessions generated several interesting ideas. The methodologies employed, the use of graphic representations and colored posits were very successful.

18.- Building prototypes is very helpful and time worthy

The teams realized that building prototypes help the customers to better understand the product and give much more valuable feedback. Plus the time needed is not that much and therefore worthy.

19.- Makerspace and other team resources were very helpful

The team was very happy to count on this resource. The courses were fantastic and the possibility to have a "makerspace-week" brilliant. They just wished they could have completely worked there during the construction phase, as they would have taken more profit of the resources.

20.- Social interactions among team members are important for the project development

Although the relationship between members was nice, this point could have been more taken into account for a better team interaction. The lessons learned sessions and team building events were considered a good tool to bring together the team members.

21.- Too many distractions make the team lose the focus and the motivation

A lot of very different workshops had to be carried out and most of them didn't had a direct impact on the team work - they were perceived as being waste of time, bringing no benefit.

Learnings of the topic expert

22.-Spending more time working together in the garage would have inspired new solutions and triggered motivation.

23.- The benefits of Scrum got lost by not using it properly

The Scrum Task Board was never properly used, the team adapted it to their necessities, which is not bad; but some of the benefits of using the system got lost (there was no moderation of the weekly scrum meeting and the members didn’t use to present their findings from the last week to the rest of the team).

24.- Stablishing a stronger vision from the beginning would have helped to keep the focus and stay motivated

The vision was stablished too late (after the first lessons learned workshop) and its presence was not palpable – little impact in the daily work.

25.- More proactivity – Exploit the tutors

The team should have been more proactive asking questions to the tutors and taking profit of the monthly sessions with them. More feedback could have led to better performance.

26.- Build prototypes to test every hypothesis is the fastest way to collect valuable feedback

The idea of testing every hypothesis with a prototype got lost and therefore the team had to invest more time to validate the hypothesis (the prototype methodology would have been more time-efficient).

27.- The idea evaluation was not complete

Regarding the product evaluation, not all three categories were always taken into account: Usability, desirability and feasibility.

28.- The team courage kept them strong against the high amount of stakeholders and requirements

The team was capable to find their way and fight for their ideas.

7. Evaluation of the knowledge base

One of the main purposes of this thesis was to implement a knowledge base that satisfies all the previously commented requirements. In order to check if these requirements were successfully addressed, a crucial part of this work is then the evaluation of the suitability and good performance of the base. By letting end-users experiment with the base, it is aimed to prove if the hypothesis made were the right ones and if our approaches to them were efficacious.

7.1 Evaluation methodology

To undertake this purpose we should first think about, who the end-user is going to be and what performances and characteristics of the knowledge base we want to measure. Attending to our concrete case, the future end-users of the base could be the students and tutors working in the project, seeking for past solutions and learnings generated; or external users that want to inspire their current project with the past experiences and designs of MyMINI Project. Moreover let´s recall that the base is thought to be optimized in the both directions of the knowledge flow, storing and using.

In the chart 7-1 it is explained how the evaluation procedure looks like depending on the different cases. Both of them will be discussed in detail in the coming chapters.

Table 7-1: Knowledge base evaluation procedure - Cases and methodologies

	END-USER PROJECT INVOLVED	END-USER EXTERNAL	FACTORS TO ANALIZE	TOOL
Documentation	Proceed with the registration of a document	X	• Time for registering • Easiness • Adequacy of parameters	• Usability test • Observation
Usage	Search for an unknown document	Search for an unknown document	• Comprehension of the hierarchies and time axis • Utility of the filters and connections • Utility of the searching rules	• Case resolution 1 (Rules) • Case resolution 2 (Hierarchies) • Usability test2

7.1.1 Feedback. Document registration

Project involved users – Document register
To begin with, let’s take the first case. The end-users were involved in the project and they aim to document new knowledge about it.
For this evaluation the important parameters to be measured are: the time needed to do the registration, the understanding of the different attributes and structures used to represent the documents in the ontology, the adequacy of the parameters chosen when it comes to describe a document and the facility to carry out the registering process.
To evaluate these factors, the team members were told to fulfil a registration form referring to one of the documents that they had generated during the project.
They were given three documents. One legend (which explains the meaning of all attributes and terms of the ontology), one picture of the hierarchical disposition of the knowledge in the base, and the registration form. (This material can be found in the annexes A8, A9 and A10).
It was needed to do an example myself first, so that they could better understand how the system works.
So as to prove the requirement of being a fast registration system, the exercise was timed. The average time needed to fulfil all fields was three minutes. Taking into account that it was the first time that the members used the system and that they had to get to know the hierarchical dispositions and the terms meanings first, it can be considered to be a very fast system. Once they automatize the knowledge base structures and attributes existing, the process could be done in less than a minute.
After registering the document, the members were given a utility test with eight questions to be rated from one to five according to their agreement to the affirmations written about the registration procedure. The questions rated factors such as the simplicity perceived, the adequacy of the parameters, or information needed to understand the system. (The utility test can be found in annex A11).

From their answers some patterns could be recognised.
The system rated very high in fields like velocity of fulfilment or the ability of fully describing the document’s content. They were all convinced that not much effort was needed to master the procedure and stated that the information given and the example were enough materials to be able to register a document by your own.
The simplicity of the procedure and the logic behind the ontology were rated from normal to good and the most disappointing part of the evaluation was that the participants were not convinced that the effort could be worthy. Nevertheless, it is positive, that exactly this aspect was rated as the worst one, because in the nearly future, the fields that they had to fulfil will be automatically done by computers. So the effort will be minimal, if any.

In table 7.1 “observation” was considered to be a second tool to evaluate the success of the procedure. During the registration process, the reactions of all participants were examined into detail. The aim was to see how they responded to the registration methodology and to corroborate from an external source, if the results captured in the utility tests were in line with reality.

It can be said, that their reaction to the registration form did not show any discrepancy in comparison to the answers given in the utility test. A couple of doubts arose at the beginning about the operation of the system and the hierarchies but afterwards, they could successfully do the registration by their own.

The results of the utility test of the six participants can be found in annexes A12 to A17.

7.1.2 Feedback. Knowledge base usage

Evaluation methodology

The knowledge usage evaluation was much more complex than the first one. Here not only project members but also outsiders had to be interviewed. An interesting point that needed a carefully reflection was the fact, that the evaluation methodology should be equal for both groups, so as to be able to compare the results; despite one group having much more information about the project and the knowledge stored than the second one.

After various meetings with my tutor, we agreed to run a case evaluation, where the participants will receive two cases. In these cases some information about the designer's situation and the knowledge that he/she would need to solve his/her problem will be given. In the first round, the participants will have to solve the case by using the methodology explained in chapter 5, entering some known parameters from the case, relating their personal situation (time availability, product familiarity etc.). Thus the members do not need to know the structure of the base to commit a search. In the second case, the hierarchies and timeframe will be given. After a brief explanation of the structure and the meaning of the different terminologies, they would have to commit the search by themselves. A utility test based on factors influencing the knowledge application will be the closure of the evaluation.

As stated above, methodology employed for the first evaluation method comes from the parameters and rules defined in chapter 5. Attending to the information provided in the case (some of it in an explicit way and some more implicitly expressed) the participants had to answer the following seven questions.

1. *Are you familiar with the product?*
2. *Do you work in an independent or in a collaborative group?*
3. *In which design phase are you at the moment, or for which design phase would the knowledge be helpful?*
4. *Which kind of activity are you performing? Does it take place at the beginning of the product development process or at the middle/end?*
5. *Is the knowledge you are looking for (the design issue) general or specific?*
6. *Is you design purpose to innovate or to improve an existent solution?*
7. *Do you have time for the search?*

The answers to these questions will be automatically translated, by means of the rules explained in table 5-1, into searching filters. The activation of the different filters according to the responses will provide the user with the most appropriate knowledge to be found in the base. (The participants will rate how helpful the filters were, in finding the right knowledge).

The second methodology is based on the hierarchies and timeline presented in chapter 4.3. This time, once the situation is presented, the same materials as the ones given in the documentation evaluation will be provided. A legend with the terminology explanation and a picture of the knowledge structuration in the base (Annexes A9 and A10). The participants will have to understand how the base is organized, in order to find the right knowledge that could help them with their design issue. Posteriorly they will have to evaluate, how relevant the documents found were.

Thanks to the utility test, the satisfaction of the participants with both methods will be measured. For the test, some factors influencing the knowledge application were taken into account. From the work of Fernandez Miguel et al. 2016, one student of my tutor, I got access to The Worker-Centred Model. This model shows among others, how some psycho-social factors can influence the worker when it comes to knowledge application.
From the factors proposed, three of them can be highlighted because of being particular important for the purpose that regards the thesis. ***Trust (1), workload (2) and past experiences (3)*** will be considered in the utility test so as to be able to evaluate if these aspects are having an impact in users showing preference for one searching tool against the other.

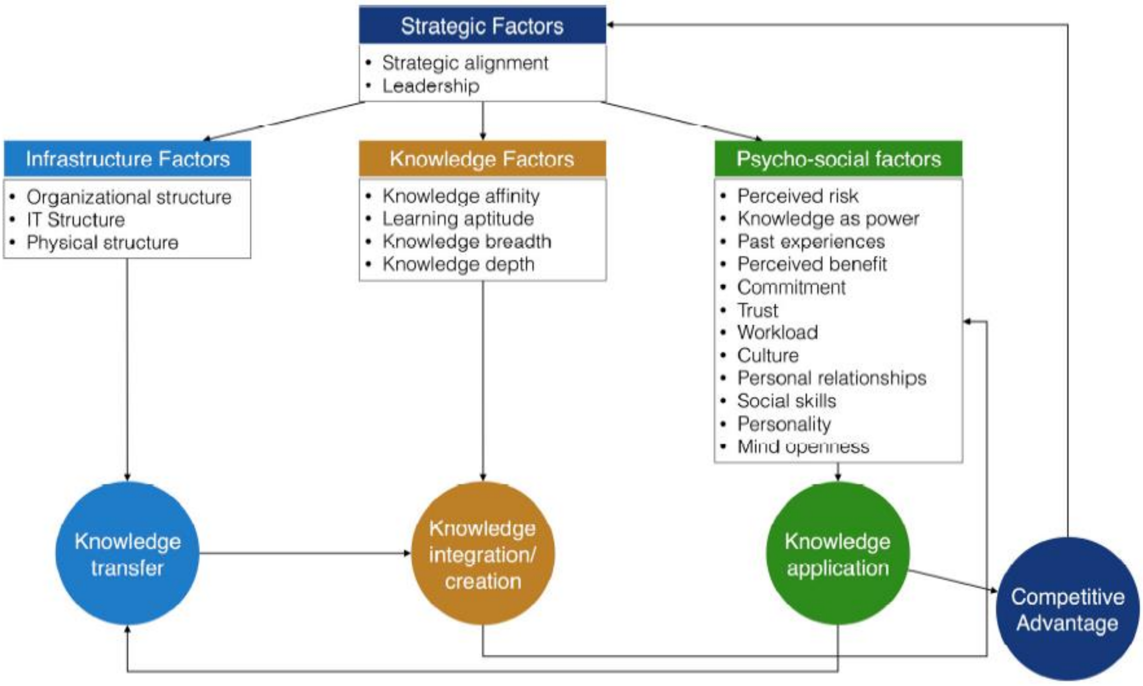


Figure 7-1: The Worker-Centred Model (Fernandez Miguel et al. 2016)

The utility test can be found in annex A19. In this test the eleven first questions are rated from one to five attending to the agreement with the sentence stated, being number twelve an open response question.

- The questions one to three are aim to check if the rules methodology (the one used in the first case – See chapter 5) are perceived as useful. The goal is to corroborate, that the questions are easy to understand and answer, furthermore that they are sufficient to find the right knowledge to solve the design issue.
- The questions four to seven address the second method evaluated, the one of the hierarchies. Here aspects like the comprehension of the hierarchical structures, the time axis or the suitability of the knowledge collected are faced.
- The questions eight to twelve compare both methods and bring to the evaluation some of the factors of The Worker-Centred Model (Fernandez Miguel et al. 2016) affecting knowledge application. Factors like trust (question 9), time management (question 10) and past experiences (question11) are considered.

Evaluation development

As shown in table 7.1 the aim of this evaluation is to check both in the case of project insiders and outsiders, if the hierarchies and time axes are understood and if the filters, connections between elements and rules are perceived as useful features.

To do so four project outsiders and four insiders participated in a role or case study evaluation where two different cases were presented. The purpose was that the students imagine themselves in a given design situation and try to approach it with the help of the implemented knowledge base.

In the following table, the evaluation plan is represented. The cases used for the evaluation can be seen in annex A18. Both groups will use the rules methodology (chapter 5) to resolve the first case; whereas the second case will be approached with the help of the hierarchies' methodology (chapter 4). After going through the two cases, the volunteers will evaluate their satisfaction with the different methodologies, in terms of easiness, intuitiveness and relevancy of the results obtained by answering the utility test.

Table 7-2: Evaluation methodology. Division in groups and cases

Outsiders	**CASE 1**	**CASE 2**	**TEST**
Persons 1-4	The participants will answer questions about their personal situation relating the project, team work etc. (according to the case). **USE OF RULES**	Taking into account the situation given, the participants will look for the right information by getting to know the knowledge base structure. **USE OF HIERARCHIES AND TIMELINES**	Usability test to evaluate the knowledge base and compare both searching methods
Insiders	**CASE 1**	**CASE 2**	**TEST**
Persons 5-8	The participants will answer questions about their personal situation relating the project, team work etc. (according to the case). **USE OF RULES**	Taking into account the situation given, the participants will look for the right information by getting to know the knowledge base structure. **USE OF HIERARCHIES AND TIMELINES**	Usability test to evaluate the knowledge base and compare both searching methods

Results

The usability test of the eight users were analysed and their answers studied. Table 7-3 shows the final results about the methods used, attending to the two participant groups being examined. At the first sight, it did not seem to be a perceptible predisposition in any of the groups for one method or the other. In both groups, half of the participants showed preference for one method; whereas the other half chose the other one. Nevertheless, a deeper study of the answers showed some trends related to being an extern or intern to the project.

- ***1º Method - Rules.*** The evaluation showed, that even when both groups considered the rules to be a good method to orient the search, easy to use and intuitive; were the project ***outsiders*** the ones that rated the relevance of the knowledge found better. This group was more open to the use of filters.

- ***2º Method - Hierarchies.*** The second method was considered to be more concrete, structured and it was also considered a good control tool for managing the search. The relevance in both teams was considered high (better as the one of the first method in both teams). The method was also considered logic and easy to use, being the project ***insiders*** the ones who rated these categories slightly better in comparison to the other group. (That was not a surprise, as they had already worked with the given structure and they already had a feeling of the knowledge stored in the base).

Table 7-3: Results evaluation. Division in groups and cases

RESULTS	Outsiders	Method 1	Method 2	Comparision M1vs.M2
	Persons 1-4	The rules were positive rated as helpful and search orienting. The relevancy was rated positively.	The hierarchies and timelines were considered logical and the knowledge provided relevant. Slightly better results than the first method.	50% vs. 50%
	Insiders	**Method 1**	**Method 2**	**Comparision M1vs.M2**
	Persons 5-8	The rules were positive rated as helpful and search orienting. The relevancy of the knowledge found got an intermediate appreciation.	The hierarchies and timelines were considered logical and the knowledge provided relevant. Moreover the learning effort to understand the system was rated as low.	50% vs. 50%

On the other hand, the psycho-social factors of The Worker-Centred Model were also rated.

- ***Trust in the filters.*** It was clearly perceived, that the project insiders rated the filters as less reliable, in comparison to the project outsiders who were more open to trust intelligent search methods.

- ***Time effectiveness.*** The time effectiveness was considered to be similar for both methods in both groups of study. Nonetheless, the effectiveness of the hierarchies over the rules method was slightly better rated in the project insiders group. (The reasoning behind this, was that once you know what you are looking for, there is no point on going through the situational rules).
- ***Past experiences.*** In both groups, past experiences working with filters were considered to be positive. Therefore, they should be predisposed and open minded to work with them.

The answers of the participants (anonymous) can be found in annexes A20 to A27. Here a couple of interesting statements of the participant are highlighted.
They considered that the rules provide more general results; therefore, if the knowledge contained in the base is not very broad, it might be worthy to have a look to the general content being available. ("*One might find useful information that otherwise, you would not have found by directly searching, as you had not thought about it*" - Participant). Nonetheless, as the amount of information grows, the hierarchies become more useful.
Some of the participants agreed that the perfect searching methodology would imply a combination of both methods, so that the personal situation can be considered and also some more technical and concrete details about the project can be used as a filtering tool. (Knowing the possibilities that the knowledge base offers, thanks to getting to know the base structure and organization).

From this evaluation it was discovered, that being part of the team or not, does not play a crucial role when using a knowledge base. The results in both study groups were pretty similar and showed that in any case, the end-users find it helpful to have some intelligent searching tools to help them orient the search. Nevertheless, being able to control the search (and visualize the knowledge) is also required, especially when one is actively working in the project and knows well the knowledge he/she is looking for.
An interesting finding that played a much more significant role that the belonging to the different study groups, was the participants' personality. The way the different persons approached the searches, defined the way they perceived the different methods and their opinions about them. Developing more studies in this area could provide with person-oriented methods that could truly satisfy the requirements of the end-user by focussing on their personalities and ways to approach the design situations.

7.2 Evaluation of the requirements achievement

Once the evaluation has been carried out and the user's feedback has been collected, the requirements set at the beginning must be analysed to check if all of them were addressed and, if they were met or not.

In table 7-4 the fourteen requirements that we aimed to achieve are depicted; furthermore one by one, of each of them will be analysed.

Table 7-4: Analysis of the requirements' achievement

Nr.	Requirement		Nr.	Requirement	
1	Adjusted to demand	✓	8	The search function must be supported	✓
2	Process oriented	~	9	Usefulness for as many end-users as possible	✓
3	Across phases + Time frame	✓	10	Visual structure with multiple representations	✓
4	Across levels	✓	11	All terms and type of relationships must be distinguishable and properly explained in a legend	✓
5	Different perspectives	✓	12	Need of keeping it updated	~
6	Simplicity in its use	✓	13	Fast to register and use knowledge	✓ ~
7	Added value must be perceptible	✓	14	Flexible to allow development iterations	✓

1. ***Adjusted to demand***. Thanks to the detailed categorisation of the knowledge entering the base, we can assure that the knowledge provided is in content and extension what the user aimed to find. With both methods, participants stated to have found relevant knowledge according to their interests and expectations.

2. ***Process oriented***. This parameter is only by half achieved. On the one hand we have the phase's timeline available to look for the knowledge required attending to the phase we are at in the new project, or the phase for which we look information for. Nevertheless, an intelligent lesson learned system that sends the users relevant information attending to their current project phase is not possible. There are two reasons that made the application of this parameter impossible. First, we are not working with a dynamic base (linked to a project evolution) and second, as every project is different (especially in innovation), the knowledge needed at the different stages vary widely. The impossibility to generalize and the lack of suitable attributes in our base to organize the information according to this parameter, has forced us to neglect it.

3. ***Across phases***. Thanks to the timeline visualization, all documents are linked to the different process phases.

4. ***Across levels.*** The hierarchies proposed allow the end-user to go through different concretization levels, to find the required knowledge. Speeding the search process, not having to pick out the documents from a wide pool of knowledge.

5. ***Different perspectives.*** The great complexity of developing ontologies makes worthy the work hand in hand with different professionals, so as to be sure that our understanding is logic and sensible. It is also helpful to consider in the design people with other personalities and ways to approach the search. As it is impossible to know who is going to reuse the base in a future, it plays an important role to have different mind-sets and points of view when developing it. To do so, literature was broadly studied and from there rose the idea to provide several different filtering methodologies. The visual hierarchies, the timeframe and the filter tool using the attributes given to the documents. Also a combination of all three is possible. This way we assume that different approaches are met and this requirement is successfully addressed.
   Even when the accomplishment of this point was assured by the literature, during the evaluation it was clear that the different participants approached the searches in different ways and they all found relevant knowledge that helped them with their specific design issue.

6. ***Simplicity in its use.*** The simplicity is a subjective parameter that had to be evaluated by the real users. From the developers side, it can be stated, that the ontology and parameters selected were done in a carefully and logical way; furthermore a legend with an explanation of the structures, terminology and an example of the registering process is for the end-users available, so as to easy the base use as much as possible. The user's feedback stated that both searching methods were considered easy to use and to get familiar with. (Providing in any case relevant knowledge).

7. ***Added value must be perceptible.*** This point also represents a subjective parameter to be evaluated. Nevertheless, relying on Lauer's (2010) work, we assumed that just by providing linkages between documents and phases will the perceived value increase.

8. ***The search function must be supported.*** As stated in point 5, allowing the end-user to look for documents at least in three different ways, help him/her to find the most suitable one attending to the knowledge sought or the individual preferences.

9. ***Suitable for as many end-users as possible.*** When developing the base, all requirements of users registering and extracting knowledge have been considered. Moreover, also the possibility of having end-users related with the current project, so as having external ones has been contemplated. The structures and attributes available aim to be intuitive and understandable for them all. (Instructions accessible). The evaluation showed that for both insiders and outsiders were the base structures logic and understandable, being the instructions given to use both methods considered sufficient and enough.

10. ***Visual structure and representation.*** A critical point to understand the structure of an ontology is to represent it in an easy way, so that the end-user can visualize it and go through it to look for a document if needed. In this knowledge base two visualizations can be found. The first one attending to the content and the second one to the time frame. Moreover, during the evaluation, it could be observed, that providing the user with a visualization tool, gave them security to approach the search and to control it.

11. ***Distinguishable terms and relationships.*** As it is explained in the literature, all terms must be different one from another and if possible have an intuitive meaning. These two things were taken into account when designing terms and connections and moreover, a detailed legend was created to provide the future users with instructions of the knowledge base operation. The participants considered the terms to be easy to understand and differentiate one from another. Being all of them meaningful and sufficient to represent the knowledge store in the base.

12. Need of keeping it updated. This point exceeds the capacity of the knowledge base designer, as it involves the people using the base. It is assumed that in agile projects the team members are responsible of keeping the base updated with the new findings. This should not be a big issue, as they are only supposed to be documenting the most relevant knowledge.

13. ***Fast to register and use knowledge.*** The aim of this work has been to reduce the attributes to just the needed ones, to properly describe the documents and stablish the connections whished. To speed the search process, a set of rules has been developed, so that searchers can directly enter the right filtering parameters. The document registration was proved to be done very quickly, as it only took the participants three minutes to completely fulfil the registration form. Being this the first time that they approached such a system, this point can be considered successfully achieved. On the other hand, the use could not be properly measured, as the answers given by the volunteers had to be translated into the right knowledge base filters by hand. Nonetheless, the time needed for the users to select the parameters to carry the search was almost negligible. (As the evaluation results show, both methods were considered to be very easy to use).

14. ***Flexible to allow development iterations.*** This base allows connecting the documents with the phases, not forcing a stiff time-oriented relationship to happen and therefore allowing designers to go back and forth when entering new knowledge and reusing the past one. So to say, the phases established are general enough to fit the designer's needs, not restringing the product evolution to the classical phases that are not usually suitable for innovation projects. The same occurs with the three hierarchies. The use of general terms would allow new branches to be created or sub-branches from existent nodes to emerge. (This would not be a problem at all as the actual system is robust and stable enough to deal with such changes. The knowledge will automatically adapt to the existent network).

As it can be seen, the design of the base has been carefully studied in order to address all the requirements found both in the literature and during the team work. It can be considered that twelve out of the fourteen requirements selected were achieved; being the remaining two either out of the designer's control or out of the scope of this Master Thesis. Nonetheless, some measures to satisfy at least partially these requirements were also considered in the base design. As it can be seen above, the achievement of all requirements were supported either by literature findings or user´s feedback.

8. Evaluation of the lessons learned sessions

Two lessons learned sessions were carried out during the process. As it has been explained in chapter 5, these two sessions aimed different purposes attending to the moment when they were run. Seeking for diverse results, shapes the sessions with different procedure methodologies; moreover, the wish to improve the outputs of the second workshop based on the first one also induced some changes.
As stated before, both workshops rely on the Schacht & Maedche (2016) cycle. In the first workshop, the process was exactly carried out like they suggests in their work. Nonetheless, the cycle for the second workshop had to be designed for this purpose following Schacht & Maedche (2016) guidelines, as they did not do it in their work. The Maturity Model is the second strong influence of this last lessons learned session.
From the cycles used in these sessions, the main five activities have been extracted and listed in the table below. All of them can be found in both cycles, as they are considered to be pillars for lessons learned workshops. Nevertheless, the methodologies to obtain the goals may vary. These variations of methodologies result from the development of the first workshop and the knowledge of the current situation of the team and their disposition towards the session.
The most relevant discoveries during the first workshop that shaped the second one were that the team was willing to express their selves, give feedback and truly help in improving the project development. Contrarily to this positive participation, their impressions about their teamwork and the project development were very negative. The best practices tended to be forgotten and just the mistakes came out in the session.
In table 8-1 the different methodologies to achieve every phase will be compared.

Table 8-1: Methodology comparison between the 1º and 2º lessons learned workshops

		METHODOLOGIES		
		1º LL WORKSHOP	2º LL WORKSHOP	COMPARISON
PHASE	Context	Manuel's interviews	Questionnaire	Both methodologies worked well. The interviews were more time consuming but therefore more technic-specific
	Info. Collection	Reflexion time at the beginning of the workshop. Areas to eliminate, reduce, increase and promote	Questionnaire	Both methodologies worked well. The questionnaires allowed the lessons learned expert to filter the results, saving the participant's time in terms of listening to duplications or irrelevant comments. It also helped in expressing the results in a more optimistic way.

	Key Events identifica-tion	Clustering the ideas and generating topics in an open discussion results into the Key Events	The Lessons Learned expert works on the results of the questionnaires - Key Events extraction	The clustering and topic generation were a little bit long but they helped participants to better understand the purpose and meaning of every step. The KE identification by the LL Expert was much quicker but the participants felt lost
	Key Events analysis	Pass the ball and 5-Whys	Use of a timeline to stablish the cause-effect relationships	The first methodology is more appropriate for sessions during the project and the second one for post-project sessions
	Determi-nation of relevancy + Plan	Open discussion	Open discussion - 3 Best / 3 Worst / The uglies	In the case of this team, forcing them to also look for positive factors was helpful

From the organizational side, both workshops were successfully run. The phases were followed and the results sought were obtained. There was an active participation, open discussion and tendency to agreement between the participants. Even when different, the workshop's methodologies were specially designed to their different purposes and therefore none is consider better than the other but more adequate to the given purpose. The willing disposition of the team members had a very positive impact, as their commitment to improve and get learnings is the driver of these kind of sessions, and without their interest in studying the project situation it wouldn't have been possible to obtain valid results.

To evaluate the perception of the participants in terms of the value added of running the two workshops and the adequacy of the methodologies used, they were asked to fulfil a short three questions evaluation to gather their opinions and beliefs. (The questions and results can be found in annex A30).

The questions were:

1. Did you like the workshops? Were they dynamic? Have they encouraged your participation?
2. Were interesting results achieved?
3. Recommendations/Critics about the workshop.

With these pretty open questions, the objective was not to direct the participant's answers but to get a feeling of the contribution of these sessions to the team.
Summarizing the results obtained, it can be said that the participants did like the workshops, as they considered that it was a good review of the work done, which helped bringing to the table issues about all topics (communication, productivity, etc.). They all considered that the techniques employed had triggered their participation and had made them aware of their work both in negative and positive terms. (Positive factors – second workshop).

About the results achieved, it was claimed that even when most of the problems were known, the sessions had helped to bring them into discussion, giving the possibility to exchange views and collaborate in looking for a solution. Moreover, the session was considered being a motivational tool, which helped to bring the team together and socialize. It was also very positive that the participants categorised the first workshop as helpful for the development of the current project and the second one, as a source of learnings for coming projects and feedback for themselves.

Regarding the third questions, the results were positive in terms of timing, participation techniques, the generated open discussion, dynamicity of the sessions and value of the results obtained. Some points to improve attained the risk of losing the point in conversations, as the open discussions happen to link to new topics; and the need of a more clearly defined agenda. Due to the non-familiarity of the participants with the knowledge management terminology, a brief explanation is needed, as well as the cause-effect chain between the session phases.

One last sign of the value of the workshops was that the participants themselves regretted not to have had more sessions during the project. They claimed they could have targeted together some issues and that it would have helped to keep the group motivated and promote the team culture. Moreover they said that they would like the tutors to be somehow involved. Probably not being present in the workshops but at least, the wanted them to be aware of their learnings and act accordingly (as many factors involving the goals consecution were harmed or could be improved because of the current poor team-department communication).

In general, the workshops, both from the participants and from the organizational sides, were considered to be successfully run and the results achieved were wide and detailed accomplishing the expectations of the sessions.

9. Discussion of the research methodology

In this chapter the discussion of the methodology presented in chapter 1.4 will be conducted. In the next table the four phases of the scientific studies which their correspondently employed methods and obtained results are represented. Each of them will be posteriorly commented.

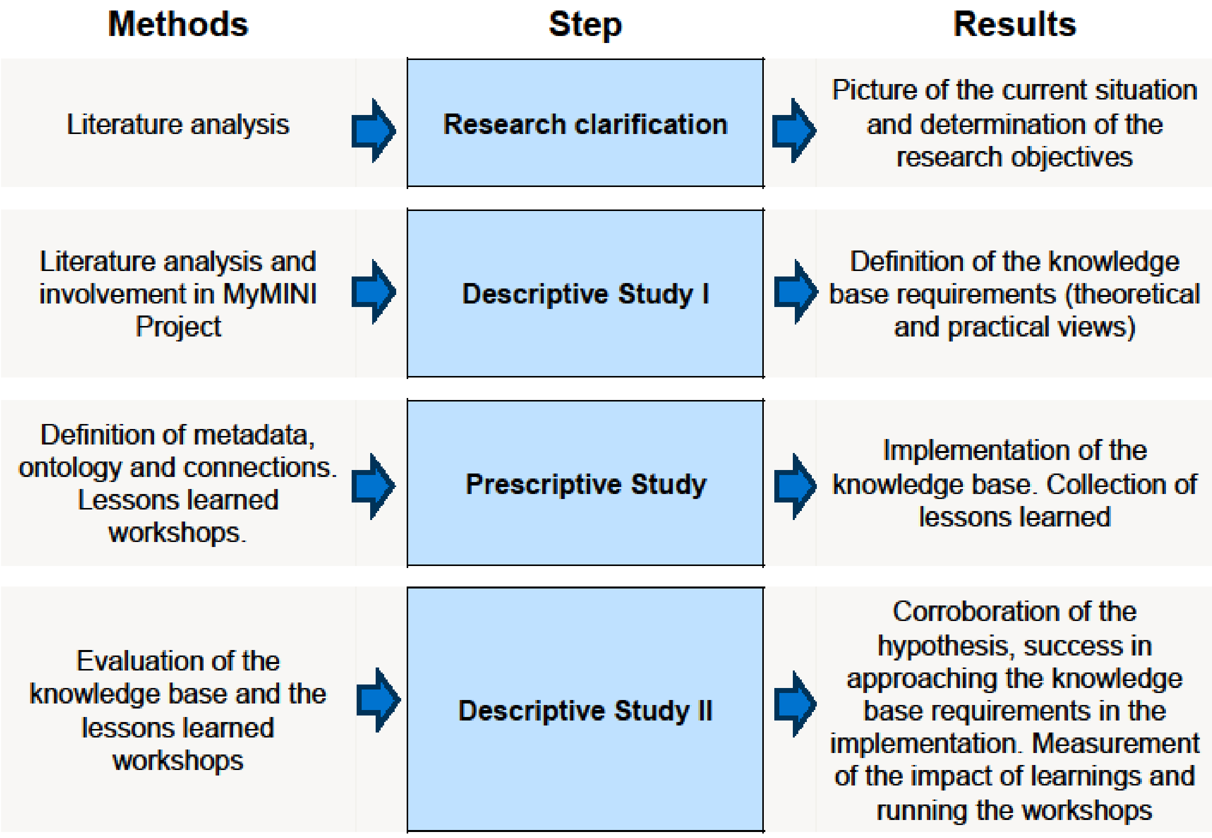


Figure 9-1:Research methodology. Methods-Steps-Results

During the ***Research Clarification*** I got the first insights of the field. My tutor provided me with some material from previous students from her and some colleagues from the department and I obtained the remaining material from online data banks like Google Scholar, Scopus or Web of Science. My little experience with scientific works harmed my efficiency in this phase, as the organization of the content found in the literature could have been done in a more organized way. Not having used before tools like OneNote or Citavi for these purposes made me underestimate the value of taking profit of them. I could have been more time-efficient by using them.

The aim of the ***Descriptive Study I*** was to deeply understand the current situation of knowledge reuse in companies and what their requirements are, in order for knowledge reuse to happen. As the field of application of the knowledge base is meant to be innovation projects in agile environments, the combination of literature research with the team work in the project was crucial. Thus, not only requirements and hypothesis about the theoretical findings were made, but also about the practical considerations gathered thanks to the collaboration with other designers. Even when I am very happy with the development of this block, it would have been positive to meet an experienced designer active in agile projects who could have given me some feedback regarding the knowledge reuse issue.

Once the key factors were recognized, the objective of the **P*rescriptive Study*** was to translate them into the output of this thesis, the implementation of the base. To do so metadata, ontology and connections were defined. This phase was the most complicated one because of the little literature especially in innovation fields and the complexity of the topic. Moreover the implementation was done in Soley, a software whose main purpose is data representation. That meant to reprogram the software to achieve the functionalities needed. The implementation performs well, but a more suitable tool could have been helpful to let the end-users directly experiment with the base and have a more loyal prototype.
Regarding the lessons learned sessions, even though the results have been very satisfactory, the development of these were not the main focus of this thesis and further research could have been done.

The last block of the study is the one where I see more room for improvement. The ***Descriptive Study II*** contains the evaluations of the knowledge base and the lessons learned (results and workshops). Due to the broad scope of the project and the limitation of time, some shortcuts and simplifications had to be done regarding some aspects of the evaluation.
On the one hand, the rules used to orient and speed the users search are based on eleven parameters that are supposed to be the most influencing ones in knowledge reuse. Nevertheless not all of them could be considered due to the lack of attributes in our documents relating these parameters. With more time, these parameters could have been deeply analysed, so as to consider if more attributes should have been defined or if there are some other parameters influencing agile projects that hadn't been considered in the first eleven.
Another issue is the number of people available to test the knowledge base. Of course, a larger number of volunteers would reinforce the validity of the results. Additionally, the evaluation itself had some imperfections and some trade-offs were committed to run it. As the two searching tools had to be evaluated, two cases were prepared to use one of the tools for each. Unluckily the limitations of the evaluation didn't allow carrying out a more thorough assessment. It would have been interesting to do two rounds of evaluations with different participants, presenting in each round one tool first. Afterwards the second tool would have been introduced and the participants would have chosen if they wanted to try the second tool or keep using the first one (known one).
Finally, I based the usability test to evaluate the performance of the base and the suitability of the different searching tools on the psycho-social factors of the Worker-Centred Model

(Fernandez Miguel et al. 2016). It was helpful to count on some parameters to do so, but the selections of these, was made broadly attending to the most obvious factors having an impact in this concrete study. Further research in this aspect could have helped coming up with a much more thorough assessment.

10. Conclusion

This Master Thesis has carried out an analysis of the literature covering design engineering fields and the theories of knowledge management and knowledge reuse. These findings were combined with the experiences collected by working hand on hand with the engineers of a real design project. The final aim of the thesis was to determine the requirements of a knowledge base that would encourage knowledge reuse in design engineering projects – especially when working in agile development conditions.

The knowledge base to be implemented contained the documents generated during the project. This led to the parallel responsibility of accepting the role of knowledge manager within the team, meaning this charge having to assure that all relevant knowledge was being documented and stored. In order to satisfy this goal, the “Idea Forms” and “Sprint” documents were designed, so that all the relevant knowledge about a given idea and the reasoning behind was documented. Additionally, lessons learned sessions were carried out. The awareness of the lack of best practices, mistakes and recommendations being documented; plus the literature considering the lessons learned collection as a crucial factor for knowledge reuse, encouraged the performance of two lessons learned workshops.

Once all the requirements from the literature and life-project were collected and analysed; fourteen aspects were considered to be necessary to ensure the efficient operation of a knowledge base that would encourage the knowledge reuse. Having these requirements set and the project knowledge gathered, the knowledge base was carefully designed and implemented in a software that allowed a pretty loyal representation of a fully performing knowledge base.
Having the base ready to use, two kinds of evaluations were run, so the requirements set could be measured in relevance and satisfaction of the implementation. From the fourteen requirements set, all of them were considered to be necessary and meaningful for the whole conception and operation of the base. Regarding the implementation of these fourteen factors, only twelve could be really addressed according to the literature and the answers of the volunteers taking the evaluation. Nonetheless, also some measures to partially satisfy the remaining two were taken into account in the base design.

From the evaluation we learned, that the base successfully satisfied the needs of both project insiders and outsiders, being their responses of the usability test very similar. A slightly predisposition and better consideration about the intelligent filters was perceived in the outsiders group; whereas the project insiders showed some predisposition or preference to have some tool to visualize the knowledge and be able to search for it in a more direct way.
An interesting fact to point out was the influence that the different personalities had in the candidates approaching the design issue. More than being familiar with the project or not, or using one searching method or the other; the main difference between participants, was the way they approached the search. According to these mental predispositions, their opinions and satisfactions with the provided methods were different, revealing a very interesting field to work with in further researches.

The two lessons learned sessions carried out in MyMINI Project, generated several learnings. The learnings from the first workshop were directly applied in the team work and the impact of these was considered to be very positive, according to the team members' feedback. On the other hand, the results obtained from the second workshop, allowed the team to learn from their successes and mistakes and so come up with important recommendations for future design projects. This knowledge reuse tool, was not only considered to be worthy, but also a socialization tool to bring the team together and satisfactorily approach problems and look for solutions and ways to improve the team work. From the impact of the lessons learned sessions in this project, it can be stated that further work in this field can definitely lead to a better understanding of the knowledge reuse sphere and the team work dynamics comprehension and support.

11. Summary and future work

The main objective of this thesis was to approach the knowledge reuse problem of current companies, with focus in design engineering processes. The purpose was to do a broad research on the field of knowledge management and knowledge reuse to afterwards implement a knowledge base that fulfils all the requirements of design engineers, so that knowledge get to be reused. To support this aim I worked for the last six months in an innovative engineering project, whose working methodologies were based on agile procedures. This was an exceptional opportunity to combine the requirements learnt form the literature with the ones formulated by the team participants. Observing for myself how knowledge is in such environments generated and documented. Moreover it helped me understand how agile teams behave and how a suitable knowledge base should support their work and so encourage the knowledge sharing and reuse.

This combination of literature research and life-work in a product development project allowed me to come up with fourteen requirements that should be fulfilled for engineers to get a suitable knowledge base which would support their work and ease the knowledge management system. According to these requirements a knowledge base was implemented.

The evaluation of the base considered the both flows of information the one entering and the one exiting the base. By means of these two evaluations it was proved that the fourteen requirements set, were meaningful and necessary. Relying on the literature and the answers of the participants, it was confirmed that twelve out of these fourteen requirements were successfully met. Moreover the knowledge base proved to be designed in a way that not only the project insiders but also the outsiders easily understood. They all were able to operate the base and find relevant knowledge attending to their design issues. It was interesting to observe, that the belonging of the participants to the first or second study group, was not the factor influencing the most their perception and opinion about the methods. Contrarily to what expected, their most significant driver influencing their impressions about the methods provided, was their personality and mental predispositions to approach a search. This finding brought to light a very interesting and complex field to study. Analyzing how users face design problems, could be a significant tool to create individualized knowledge bases that really can impulse and encourage knowledge reuse, as it will be done in the more natural way, attending the kind of user personality.

As I was the knowledge management expert of the team, taking care of knowledge not getting lost was also my responsibility. That is why during the project two lessons learned sessions were carried out; with the aim of both: improving our performance during the project lifetime and supporting future projects.

The results of the lessons learned sessions were very satisfactory. Not only the methodologies helped obtaining meaningful learnings that afterwards were successfully applied (having a positive impact in the team work), but the team itself considered such workshops as necessary and valuable for the improvement of the team performances and to create a team culture where members can get together to share, discuss and solve the existing problems. Therefore, it can be stated that further work in this field can definitely lead to a better understanding of the knowledge reuse sphere and the team work dynamics comprehension and support.

In short, the implementation of this knowledge base attending to the fourteen requirements seemed to be the first step in the right direction to meet designers' necessities and so promote knowledge reuse in this field. As mentioned in chapter 9 some improvements can be done in terms of the evaluation methodologies and the implementation of the knowledge base in a more appropriate software program. Nonetheless this study corroborated some of the hypothesis made by evaluating the validity of the fourteen requirements. From now on, furthers studies can take place based on these facts.

Analyzing the field from a broader view and taking into account all the knowledge gained about the designers work and the agile methodologies that are starting to impose in product development processes; it can be said, that the next developments in knowledge bases point to the use of artificial intelligence. Artificial intelligence could provide the interconnections between knowledge items that designers seek; moreover, it could study the designer context to look for similarities in previous works and make him/her suggestions of using appropriate knowledge found in the base; furthermore it would even avoid the documentation effort. Constructing intelligent knowledge bases, knowledge reuse will not be a problem anymore, but a reality.

12. Bibliography

Ahmed, S., Kim, S., Wallace, K. M. (2004). *Understanding the Knowledge Need of Novice Designers in the Aerospace Industry*. Design Studies 25, 2, pp. 155-173. ISSN: 0142-694X.

Ahmed, S. (2005). *Encouraging reuse of design knowledge: a method to index knowledge*. Design Studies, 26(6), pp. 565-592.

Alavi M. and Leidner D. E. (2001). Review: *Knowledge Management and Knowledge Management Systems*: *Conceptual Foundations and Research Issues*. MIS Q., 25 (1), pp. 107–136.

Ameri, F., Dutta, D. (2005). *Product lifecycle management: closing the knowledge loops.* Computer-Aided Design and Applications 2 (5), pp. 577–590.

Baxter, D., Gao, J., Case, K., Harding, J., Young, B., Cochrane, S., Dani, S. (2007). *An engineering design knowledge reuse methodology using process modelling*. Research in Engineering Design 18 (1), pp. 37-48. (DOI: 10.1007/s00163-007-0028-8)

Bergen, H., Kissel, M., Golovatenko, A. and Grüner, P. (2011). Soley Studio [computer software]. Munich: Soley.

Blessing, L., Chakrabarti, A. (2009). *DRM, a Research Design Methodology*. London. Springer-Verlag.

Boh, W. F. (2008). *Reuse of knowledge assets from repositories: A mixed methods study.* Information & Management 45(6), pp. 365-375.

Böhmer, A., Richter, C., Hostettler, R., Schneider, P., Plum, I., Böhler, Lindemann U., Conrad J., and Knoll, A. (2016). *Think. Make. Start. - An agile framework.* In DS 84: Proceedings of the DESIGN 2016, 14th International Design Conference.

Bowen, S. J., & Brown, D. R. (2000). U.S. Patent No. 6,094,649. Washington, DC: U.S. Patent and Trademark Office.

Busby, J. S. (1999). *An assessment of post-project reviews.* International Journal of Project Management, 30 (3), pp. 23-29.

Carro Saavedra C., Serrano Villodres T., Lindemann U. (2016). *Review and Classification of Knowledge in Engineering Design*. IcoRD2017. Technische Universität München.

Chau, T., Maurer, F., Melnik, G. (2003). *Knowledge sharing: agile methods vs. Tayloristic methods*. Twelfth IEEE International Workshops 9-11 June 2003, pp. 302–307. (DOI: 10.1109/ENABL.2003.1231427)

Cheung, P.-K., P. Y. Chau and A. K. Au (2008). *Does knowledge reuse make a creative person more creative?* Decision Support Systems 45 (2), pp. 219-227.

Chou, T. C., Chang, P. L., Cheng, Y. P., & Tsai, C. T. (2007). *A path model linking organizational knowledge attributes, information processing capabilities, and perceived usability.* Information & Management, 44(4), pp. 408-417**.**

Cohen D. (December 2006). *What is your return on knowledge?* Harvard Business Review.

Conrad, J., Deubel, T., Köhler, C., Wanke, S., Weber, C. (2007). *Comparison of knowledge representation in PDM and by semantic networks.* International conference on engineering design (ICED 07). Paris, 28.08.-31.08.2007. Glasgow: the Design Society 2007, pp. 583-584. ISBN: 1-904670-02-4.

Collier, B., DeMarco, T., & Fearey, P. (1996). *A defined process for project post mortem review*. IEEE software, 13(4), pp. 65-72.

Conway, A. P., & Ion, W. J. (2013). *Enhancing the design dialogue: an architecture to document engineering design activities.* Journal of Engineering Design, 24 (2), 140-164.

COVEO. (2014, December). [Web Page] Retrieved from *http://www.coveo.com/en/company/news-releases/2014/new-study-reveals-knowledge-workers-mostly-do-rework*

Cross, M. S.; Sivaloganathan, S. (2007). *Specialist knowledge identification, classification, and usage in company-specific new product development processes*. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 221 (8), pp. 1285–1298. (DOI: 10.1243/09544054JEM580)

Du, J., Liu, J. (2011). *Knowledge management for product development*: A review. Computer-Aided Design and Computer Graphics (CAD/Graphics), 2011 12th International Conference on: IEEE.

Erden, Z. (2011). *Phases of Engineering Design.* MECE 202 Principles of Mechatronics design. Lecture Notes. Department of Mechatronics.

Fernandez Miguel R., Carro Saavedra C., Lindemann U. (2016). *Factors influencing knowledge application: A review from the knowledge management field*. International Design Conference - Design 2016.

Firdaus M., Wang H., Qin H., Liu Y. (2015). *Digital repository for design knowledge reuse*. International conference on engineering design (ICED 15).

Fowler, M., & Highsmith, J. (2001). *The agile manifesto*. Software Development, 9(8), pp. 28-35.

Fruchter R., Demian P., (2002). *Knowledge Management for Reuse*. (Conference Proceedings). Department of Civil and Environmental Engineering, Stanford University.

Garud, R., & Kumaraswamy, A. (2005). *Vicious and virtuous circles in the management of knowledge: The case of Infosys Technologies*. MIS quarterly, pp. 9-33.

Gold A. H., Malhotra A., Segars A. H. (2001). *Knowledge Management: An Organizational Capabilities Perspective*. J. Manag. Inf. Syst., 18, (1), pp. 185–214, 2001.

Gruber, T. R. (1995). *Toward principles for the design of ontologies used for knowledge sharing*. International journal of human-computer studies, 43(5), pp. 907-928.

Hall R., Andriani P. (2002). *Managing Knowledge for Innovation*. Long Range Planning Journal 35 (1), pp. 29-48.

Helbig H. (2006). *Knowledge Representation and The Semantics of Natural Language*. Berlin: Springer 2006. ISBN: 978-3-540-24461-5.

Hess E. D., Liedtka J.M. (2016). *The Learning Launch: How to Grow Your Business With the Scientific Method*. Darden Ideas to Action – Design Thinking, Enterpreneurship, Innovation and Growth. (June 2016).

Hicks, B. J.; Culley, S. J.; Allen, R. D.; Mullineux, G. (2002). *A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design.* International Journal of Information Management 22 (4), pp. 263-280.

Hoeschl, H. C., & Barcellos, V. (2006, August). *Artificial Intelligence and Knowledge Management*. In IFIP International Conference on Artificial Intelligence in Theory and Practice (pp. 11-19). Springer US**.**

Hubka, V. And Eder, W.E. (1996). Design Science: Introduction to the Needs, Scope and Organization of Engineering Design Knowledge, Springer-Verlag, London, UK

Irlinger, R. (1998). *Methoden und Werkzeuge zur nachvollziehbaren Dokumentation in der Produktentwicklung.* Zugl. Dissertation Technische Universität München (1998). Aachen: Shaker 1998. ISBN: 978-3-8265-4714-0.

Ishino, Y., Jin, Y. (2002). *Acquiring engineering knowledge from design processes*. AI EDAM 16 (02), pp. 73–91.

Kankanhalli, A., Tanudidjaja, F., Sutanto, J., Tan, B. C. Y. (2003). *The role of IT in successful knowledge management initiatives*. Commun. ACM (Communications of the ACM), 46 (9), pp. 69–73. (DOI: 10.1145/903893.903896).

Kim, J., & Gil, Y. (1999, July). *Deriving Expectations to Guide Knowledge Base Creation*. In AAAI/IAAI (pp. 235-241).

Knapp, L., M. A. R. K., & Comaden, M. E. (1979). *Telling it like it isn't: A review of theory and research on deceptive communications*. Human Communication Research, 5(3), 270-285.

Koenig, M. E. D. (2012): *What is KM? Knowledge management explained*. KMWorld Magazine.

Krcmar, H. (2005). Informationsmanagement. 3. Aufl. Springer 2005. ISBN: 3-540-23015-7.

Kuan. Y. W. (2005). *Critical success factors for implementing knowledge management in small and medium enterprises*. Industrial Management & Data Systems 105 (3), pp. 261–279. (DOI: 10.1108/02635570510590101)

Kuffner, T. A., & Ullman, D. G. (1991). *The information requests of mechanical design engineers*. Design Studies, 12(1), pp. 42-50.

Künzel, F. (2016). *Eingliederung nutzerzentrierter und agiler Methoden in den Innovationsprozess: Analyse, Anwendung und Bewertung im Rahmen eines studentischen Konstruktionsprojekts.* (Semester Thesis. Technische Universität München).

Kurz, B. (2016). *Schnittstellen von Anforderungen in der innovativen und interdisziplinären Produktentwicklung.* (Master Thesis. Technische Universität München).

Lauer, W. M. (2010). *Integrative Dokumenten-und Prozessbeschreibung in dynamischen Produktentwicklungsprozessen*. (Doctoral dissertation, Technische Universität München).

Li, Z.; Liu, M.; Ramani, K.: *Review of Product Information Retrieval: Representation and Indexing.* Proceedings of 2004 ASME Design Engineering Technical Conferences & Computers and Information in Engineering Conference. Salt Lake City, 28.09.–02.10.2004. ISBN: 0-791-83742-4.

Li, Shaozi; Pan, Wei; Yong, Jianming. (2008). *Study on Construction of Enterprise Knowledge Portal Based on Web2.0*. In Proceedings of the IEEE International Symposium on IT in Medicine and Education (ITME 2008). IEEE Press. ISBN: 9781424425112.

Liebowitz, J. (Ed.). (1999). *Knowledge management handbook*. CRC press.

Liebowitz, J. (2001). *Knowledge management and its link to artificial intelligence*. Expert systems with applications, 20(1), pp. 1-6**.**

Ling, T. N., Yih, G. C., Eze, U. C., Gan G. G. G. (2008). *Knowledge Management drivers for organisational competitive advantage*. Proceedings of Applied International Business Conference.

Majchrzak, A., L. P. Cooper and O. E. Neece (2004). *Knowledge reuse for innovation*. Management science 50(2), pp. 174-188.

Majchrzak, A., Wagner, C., & Yates, D. (2012). The impact of shaping on knowledge reuse for organizational improvement with Wikis. MIS Quarterly, February.

Markus M. L. (20011). *Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success*. J. Manag. Inf. Syst., 18 (1), p. 36.

Marsh, M. J. (1997). *The capture and utilisation of experience in engineering design*. Dissertation University of Cambridge.

McMahon, C., Lowe, A., Culley, S. (2004). *Knowledge management in engineering design - Personalization and codification*. Journal of Engineering Design, 15 (4), pp. 307-325. (DOI: 10.1080/09544820410001697154).

Milton, N. R. (2007). *Knowledge acquisition in practice: a step-by-step guide*. Springer Science & Business Media.

Morales Quiles, J. (2016). *Characterizing Situations of Knowledge Reuse during the Engineering Design Process* (Master Thesis. Technische Universität München).

Musen M. A. (1991). *Dimensions of knowledge sharing and reuse*. Computers and biomedical research 25, pp. 435-467.

Neches, R., Fikes, R. E., Finin, T., Gruber, T., Patil, R., Senator, T., & Swartout, W. R. (1991). *Enabling technology for knowledge sharing*. AI magazine, 12(3), 36.

Nemati H. R., Steiger D.M., Iyer L. S., Herschel R. T. (2002). *Knowledge warehouse: an architectural integration of knowledge management, decision support, artificial intelligence and data warehousing.* Decision Support Systems 33, pp. 143–161. (DOI: 10.1016/S0167-9236(01)00141-5)

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford university press.

Paetsch, F., Eberlein, A., & Maurer, F. (2003, June). *Requirements Engineering and Agile Software Development*. In WETICE (Vol. 3, p. 308).

Pahl, G., Beitz, W. (2013). *Engineering design: a systematic approach*. Springer Science & Business Media.

Prencipe, A., & Tell, F. (2001). *Inter-project learning: processes and outcomes of knowledge codification in project-based firms*. Research policy, 30 (9), pp. 1373-1394.

Postrel, S. (2002). *Islands of shared knowledge: Specialization and mutual understanding in problem-solving teams*. Organization Science, 13(3), pp. 303-320.

Qumer, A.; Henderson-Sellers, B. (2008). *An evaluation of the degree of agility in six agile methods and its applicability for method engineering*. Information and Software Technology 50 (4), pp. 280–295. (DOI: 10.1016/j.infsof.2007.02.002)

Sainter, P.; Oldham, K.; Larkin, A.; Murton, A.; Brimble, R. (2000). *Product knowledge management within knowledge-based engineering systems.* A review. Design Engineering Technical Conference and Computers and Information in Engineering, 2000. Conference on: Baltimore Maryland.

Salas de Arribas G. (2015). *Developing a Knowledge Base to Support Junior Product Developers.* (Master Thesis. Technische Universität München).

Schacht, S., Maedche, A. (2016). *A Methodology for Systematic Project Knowledge Reuse. Innovations in Knowledge Management*. Razmerita, L. (Eds.), Springer (Berlin), 2016, pp. 19-44.

Schäfer, T. (2006). *Marktorientierte Produktentwicklung und optimierte Time-to-Market durch den Einsatz eines Produkt Information Management Systems (PIM) im Gerätebau*. Dissertation, Universität Duisburg-Essen**.**

Schäppi, B.; Andreasen, M., Kirchgeorg, M., Radermacher, F.-J. (2005). *Handbuch Produkt-entwicklung*. München: Carl Hanser 2005. ISBN: 3-446-22838-1.

Schindler, M., & Eppler, M. J. (2003). *Harvesting project knowledge: a review of project learning methods and success factors.* International journal of project management, 21(3), pp. 219-228.

Schmitt, R. (2000). *Unternehmensübergreifender Engineering Workflow***.** Dissertation, Technische Universität Clausthal.

Schulz, A. P. (2002). *Systemtechnische Gestaltung der Informationsarchitektur im Entwicklungsprozess.* Zugl. Dissertation Technische Universität München. München: Utz 2002. ISBN: 3-831-60147-X.

Secchi, P., Ciaschi, R., Spence, D. (1999). *A Concept for an ESA lessons learned system*. Proceedings of Alerts and An Effective Way to Prevent Failures and Problems, (Technical Report WPP-167), Noordwijk, The Netherlands, ESTEC (1999), pp. 57-61.

Serrano, T. (2016). *Review and Classification of Types of Knowledge in Engineering Design*. (Master Thesis. Technische Universität München).

Staab S., Schnurr H-P., Studer R., Sure Y. (2001). *Knowledge Processes and Ontologies*. IEEE Intelligent Systems 16 (1), pp. 26-34.

Stewart T. A. (1997). *Intellectual capital: the new wealth of organizations*. Currency Doubleday, New York (1997).

Szulanski G. (1996). *Exploring Internal Stickiness: Impediments to the Transfer of Best Practice within the Firm*. Strateg. Manag. J., 17 (1), pp. 27–43.

Szykman, S., Sriram R. D., Bochenek, C., Racz, J. W. and Senfaute, J. (2010). Design repositories: engineering design's new knowledge base. National Institute of Standards and Technology. IEEE-IS-15-3-d.

Van Aken, J. E. (2005). *Valid knowledge for the professional design of large and complex design processes.* Design Studies 26 (4), pp. 379–404.

Von Zedtwitz, M. (2002). *Organizational learning through post–project reviews in R&D.* R&D Management, 32(3), pp. 255-268**.**

Wang, W., Gan, C., & Zheng, D. (2008, December). *Study on construction of enterprise knowledge portal based on Web2. 0.* In IT in Medicine and Education, 2008. ITME 2008. IEEE International Symposium on (pp. 621-625). IEEE.

Weber, R., Aha, D. W., & Becerra-Fernandez, I. (2001). *Intelligent lessons learned systems*. Expert systems with applications, 20(1), pp. 17-34.

White M. L., Cohan. A. (2010). *A Guide to Capturing Lessons Learned*. The Nature Convervancy.

White. S. (2005, July 2). *Better computational descriptions of science*. Scientific Computing *World. [Web page] Retrieved from: https://www.scientific-computing.com/feature/better-computational-descriptions-science*

Whitney, D. E.; Dong, Q.; Judson, J.; Mascoli, G. (1999). *Introducing Knowledge-Based Engineering Into an Interconnected Product Development Process*. In: Proceedings of the 1999 ASME International Design Engineering Technical Conferences & Computers and Information in Engineering Conference. Las Vegas, 12.09.-15.09.1999.

Wiig, K. M. (1997). *Integrating intellectual capital and knowledge management*. Long range planning, 30(3), pp. 99-405. (DOI: 10.1016/S0024-6301(97)90256-9).

Williams, T., Ackermann, F., Eden, C., & Howick, S. (2001). *The use of project post-mortems.* Project Management Institute Annual Symposium, Nashville, Tenessee, Nov 2001.

Yoo, S. B., & Kim, Y. (2002). *Web-based knowledge management for sharing product data in virtual enterprises*. International journal of production economics, 75(1), pp. 173-183.

Zdrahal, Zdenek; Mulholland, Paul; Domingue, John; Hatala, Mark. (2000). *Sharing engineering design knowledge in a distributed environment*. Behaviour & Information Technology 19 (3), pp. 189–200.

13. List of figures

Figure 1-1: Some members of MyMINI project – MINI Cooper borrowed for the project ... 6
Figure 1-2: Overview of the research methodology followed in this thesis 8
Figure 1-3: Gantt chart of the main stages 8
Figure 2-1: Development from data to knowledge 14
Figure 2-2: Relationships between data, information, knowledge and decision making (Hicks et al. 2002) 14
Figure 2-3: Knowledge Management process phases (Schacht & Maedche 2016) 15
Figure 2-4: Knowledge spiral – Acquisition phase (Nonaka & Takeuchi, 1995) 16
Figure 2-5: Knowledge Integration 18
Figure 2-6: Design process phases (Erden 2011) 23
Figure 2-7: Knowledge levels and states of applicability (Hicks et al. 2002) 24
Figure 2-8: Types of knowledge - classification. (Serrano 2016) 26
Figure 2-9: Screenshot of the list of search results (Firdaus et al. 2015) 29
Figure 2-10: Screenshot of the detail design interface (Firdaus et al. 2015) 30
Figure 2-11: Information flows in knowledge bases 32
Figure 2-12: Attributes classification (Lauer 2010) 37
Figure 2-13: Categories and elements of metadata (Yoo & Kim 2002) 38
Figure 2-14: Lauer program implementation - 5 parameters 41
Figure 2-15: Parameter-based link between product data, people and processes (Translation of Schmitt 2000) 42
Figure 2-16: Simple example of an ontology – Animal kingdom (White 2005) 43
Figure 2-17: Steps to create an ontology (Staab et al. 2001) 44
Figure 2-18: Lessons Learned classification according to impact of reuse and timing (Schact & Maedche. 2016) 48
Figure 2-19: Double-Cycled Lessons learned process (Schact & Maedche 2016) 49
Figure 3-1: Scrum board - Team Modular 54
Figure 3-2: Scrum board - Team MoodMusic 54
Figure 3-3: MyMINI Project Cloud. Knowledge documentation 55
Figure 3-4: Key factors of agile working teams 58
Figure 4-1: MyMINI Project development phases 63

Figure 4-2: Development phases of the idea MoodMusic..63
Figure 4-3: Development phases of the idea Modular...63
Figure 4-4: Knowledge structuration. Background & decision support hierarchy................66
Figure 4-5: Knowledge structuration. Ideas hierarchy 67
Figure 4-6: Knowledge structuration. Lessons Learned hierarchy.......................................67
Figure 4-7: Knowledge structuration. Timeframe - Composition of the global project phases and the ideas development phases 68
Figure 4-8: Example of "contains" linkage...69
Figure 4-9: Example of "belongs" linkage 70
Figure 4-10: Example of "is" linkage 70
Figure 4-11: Nodes shaping the MyMINI Project knowledge base – Screenshot of a node-property window...73
Figure 4-12: Color differentiation between edge types 74
Figure 4-13: Implementation of the knowledge base in Soley. All documents, phases and connections are shown...74
Figure 4-14: Soley hierarchical representation. Background & Decision Support hierarchy as an example..75
Figure 4-15: Soley representation. Timeframe..75
Figure 4-16: Soley nodes legend. Colors and shapes distinction. 76
Figure 4-17: Template to registry a new document. Registration example...........................77
Figure 4-18: Data properties window in Soley. Document of the example 78
Figure 4-19: Smart selector window in Soley. Filtering tool - Example of search 79
Figure 6-1: Methodology for the first lessons learned workshop...85
Figure 6-2: Lessons learned gathering. Managerial and technical areas 86
Figure 6-3: Key events identification process - 1º Lessons learned workshop 87
Figure 6-4: Key events analysis process - 1º Lessons learned workshop.............................88
Figure 6-5: Board with results1 - 1º Lessons learned workshop 89
Figure 6-6: Board with results2 - 1º Lessons learned workshop 89
Figure 6-7: The five levels of the Maturity Model (White & Cohan 2010) 94
Figure 6-8: Lessons learned type 1 cycle - Adaptation of Schacht & Maedche's (2016) work 95
Figure 6-9: 2º Lessons learned workshop methodology...96

Figure 6-10: Example of a timeline - Modular idea 97
Figure 6-11: Filled timeline - Modular idea 98
Figure 6-12: Filled timeline - MoodMusci idea 98
Figure 7-1: The Worker-Centred Model (Fernandez Miguel et al. 2016) 112
Figure 9-1:Research methodology. Methods-Steps-Results 122

14. List of tables

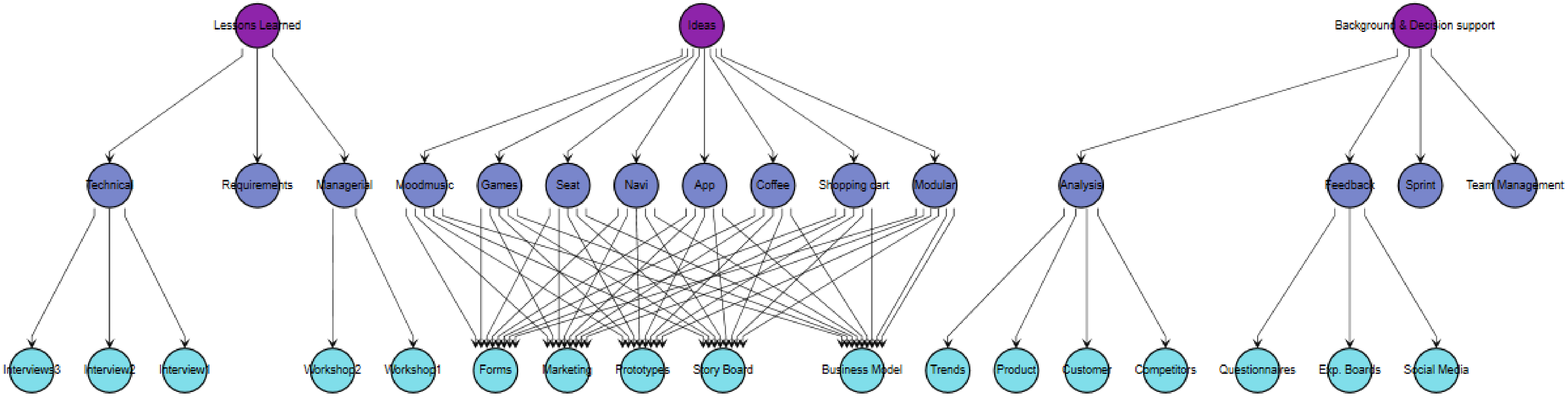
Table 1-1: Work breakdown structure of the project 8
Table 1-2: Bar chart – Tasks breakdown among the 28 weeks 12
Table 2-1: Problems of knowledge reuse 18
Table 2-2: The eight knowledge base requirements (Translation of Lauer 2010) 34
Table 2-3: Requirements for knowledge bases and companies to encourage knowledge reuse 35
Table 2-4: List of structural features regarding the documents analyzed (Translation of Lauer 2010) 39
Table 2-5: List of process features regarding the documents analyzed (Translation of Lauer 2010) 39
Table 2-6: Composition of the describing parameters for documents and processes. (Translation of Lauer 2010) 40
Table 2-7: Steps to create an ontology, with explanation (Staab et al. 2001) 44
Table 4-1: Composition of the requirements set by knowledge base theories and agile methodologies 61
Table 4-2: Recompilation of documents and input sources in MyMINI knowledge base 65
Table 4-3: Composition of the describing parameters for documents and processes 2 (Translation of Lauer 2010) 71
Table 4-4: Recapitulation of the fourteen requirements for this knowledge base 72
Table 5-1: Rules and filter parameters to support the search 83
Table 6-1: Recapitulation of the learnings - 1º Lessons learned workshop 90
Table 6-2: Learnings from Modular - 2º Lessons learned workshop 100
Table 6-3: Learnings from MoodMusic - 2º Lessons learned workshop 101
Table 6-4: General learnings - 2º Lessons learned workshop 102
Table 7-1: Knowledge base evaluation procedure - Cases and methodologies 109
Table 7-2: Evaluation methodology. Division in groups and cases 113
Table 7-3: Results evaluation. Division in groups and cases 114
Table 7-4: Analysis of the requirements' achievement 116
Table 8-1: Methodology comparison between the 1º and 2º lessons learned workshops 119

Annexes

A1 Hierarchies' visualization in Soley A-3
A2 Manuel's interviews. Technical learnings – Context setting....A-4
A3 Analysis of the parameters affecting knowledge reuse A-9
A4 Results A – 1º Lessons learned workshop A-10
A5 Results B – 1º Lessons learned workshop A-11
A6 Timeline Modular –2º Lessons learned workshop....A-12
A7 Timeline Modular –2º Lessons learned workshop....A-13
A8 Document-registry form A-14
A9 Hierarchies and phases. Registration material A-15
A10 Terms explanation. Registration material A-16
A11 Usability test. Document registration - Fragebogen zur System-Gebrauchstauglichkeit A-17
A12 Usability test. Document registration – Person 1 ....A-19
A13 Usability test. Document registration – Person 2 ....A-20
A14 Usability test. Document registration – Person 3 ....A-21
A15 Usability test. Document registration – Person 4 ....A-22
A16 Usability test. Document registration – Person 5 ....A-23
A17 Usability test. Document registration – Person 6 ....A-24
A18 Cases for the knowledge base usage evaluation A-25
A19 Usability test. Knowledge base usage evaluation....A-26
A20 Usability test. Knowledge base usage evaluation – Project insider....A-28
A21 Usability test. Knowledge base usage evaluation – Project insider A-30
A22 Usability test. Knowledge base usage evaluation – Project insider....A-32
A23 Usability test. Knowledge base usage evaluation – Project insider....A-34
A24 Usability test. Knowledge base usage evaluation – Project outsider....A-36
A25 Usability test. Knowledge base usage evaluation – Project outsider....A-38
A26 Usability test. Knowledge base usage evaluation – Project outsider....A-40
A27 Usability test. Knowledge base usage evaluation – Project outsider....A-42
A28 Example of a Sprint document....A-44
A29 Example of an Idea Form document....A-47

A30 Feedback from the participants of the lessons learned workshops. A-49

A1 Hierarchies' visualization in Soley



A2 Manuel’s interviews. Technical learnings – Context setting

INTERVIEWLEITFADEN

Interview-ID:______

Interviewer:____

Datum:___.___.2016

Beginn:__________Uhr Ende:__________Uhr

Datenintegration

1) An welchen Prototypen haben Sie bis jetzt entwickelt?

____

____

____

2) Hatten Sie genügend Daten um die Ideen zu evaluieren (z.B. um Hypothesen zu testen)?

O ja O nein

3) Welche Daten hätten Ihnen bei der Evaluation der Ideen geholfen?

____

____

____

4) Welche Probleme hatten Sie bei der ingenieurstechnischen Umsetzung der Ideen?

____

____

____

5) Konnten Sie die Probleme lösen und wenn ja, wie?

____

____

____

6) Welche Auswirkungen haben sich durch die Beantwortung bzw. die Nichtbeantwortung, der durch die Probleme ausgelösten Fragestellungen, ergeben?

____

____

____

7) Welche Informationen konnten Sie nutzen, um die ingenieurstechnischen Fragestellungen zu beantworten?

____

____

____

8) Welche Informationen hätten Ihnen bei der Lösung der ingenieurstechnischen Fragestellungen geholfen?

____

____

____

9) Wo sehen Sie Verbesserungspotentiale bei dem Einsatz von Daten für die Umsetzung der Prototypen?

____

____

____

10) Welche der folgenden Daten hätten Ihnen bei der Evaluierung der Ideen bzw. bei der ingenieurstechnischen Umsetzung geholfen? Bewerten Sie diese von 1 (nicht hilfreich) bis 5 (sehr hilfreich).

Datenkategorie Beispieldaten	Ideen-evaluation	Ingenieurs-technische Umsetzung
Airbag Steuergerät Beschleunigung, Geschwindigkeit, Gas- und Bremspedalstellung		
Multimedia-Einheit Namen, Anschriften, Telefonnummern und Email-Adressen aus verbundenen Handys sowie Anzahl von CD und USB-Stick Wechsel		
Fehlerspeicher Daten zu Fehlern und ungewöhnlichen Betriebssituationen mit zugehörigem Kilometerstand und Fahrzeuggeschwindigkeit		
Navigationsdaten		

Standort des Fahrzeugs und im Navigationsgerät gewählte Ziele		
Autoschlüssel Fahrgestellnummer, Kilometerstand und Tankinhalt		
Einstellung der Sitzposition Veränderung der Sitzposition		
Tür- und Fensterposition Statusmeldungen z.B. über Öffnung von Fenstern und Türen		
Software Zugriff und Ferndiagnosedaten zur Fahrzeugsoftware		
Motorelektronik und Batterie Fahrzeiten auf Autobahn, Landstraße oder Stadtgebiet sowie Daten zur Auf- bzw. Entladung der Batterie mit Uhrzeit und Kilometerstand im Falle von E-Fahrzeugen		

11) Erklären Sie kurz wie diese Daten Ihnen bei der Umsetzung geholfen hätten.

____

____

____

____

____

____

Einflussfaktoren

12) Bewerten Sie den Einfluss den die aufgeführten Faktoren auf Ihre Arbeit im Rahmen des MyMini Projekts bis zu diesem Zeitpunkt hatten.

3 = sehr positiver Einfluss

2 = mittelmäßig positiver Einfluss

1 = leicht positiver Einfluss

0 = kein Einfluss

-1 = leicht negativer Einfluss

-2 = mittelmäßig negativer Einfluss

-3 = stark negativer Einfluss

Einflussgrad der wechselnden Marktanforderungen auf Prototypenentwicklung (z.B. E-Mobilität)	
Grad der Anpassung bereits bestehender Entwicklungsprozessansätze (z.B. Anpassung von Scrum)	

Güte der Definition und Koordination von Entscheidungspunkten (z.B. Jour Fix Termin)	
Güte der Definition und Koordination von Informationsflüssen (z.B. Einsatz von Slack)	
Regularien für Automobilzulassung (z.B. Sicherheitsvorgaben an Innenraumgestaltung)	
Stand der für die Prototypenentwicklung relevanten Technologien (z.B. 5G)	
Anzahl und Ausgestaltung von Prozessen	
Anzahl und Komplexität der Aufgaben sowie Güte der Aufgabeverteilung	
Stand der intern für die Prototypenentwicklung zur Verfügung stehenden relevanten Technologien (z.B. 3D-Druck)	
Bereitstellung der benötigten Werkzeuge durch TechTalents Stipendium für Maker Space	
Zusammenarbeit der Teammitglieder	
Unterstützung durch HIWI bzgl. Prozesswissen speziell zu agilen Methoden und Feedback durch Annette	
Verfügbarkeit von Arbeitsmaterialien für Prototypen (z.B. Holzplatten)	
Zusammenstellung des Teams durch Lehrstuhl	
Bereitstellung Raum, Fertigungsanlagen und Testfahrzeug durch Lehrstuhl	
Aufteilung (natürlich oder methodisch) von Rollen im Team	
Aufgabenverteilung und -kontrolle an Teammitglieder	
Entscheidungs- und Handlungsfreiheit der Teammitglieder	
Einnahme von situativer Führungsrolle von Teammitgliedern mit spezifischen Fachkenntnissen	
Engagement des Lehrstuhls (z.B. Stunden die Betreuer direkt im Projekt investieren)	
Effektivität der Lehrstuhlunterstützung	
Anreize für einen erfolgreichen Projektverlauf (z.B. Abschluss Masterarbeit)	
Einflussgrad der Zielmarktdemografie auf Prototypenentwicklung	
Einflussgrad der gesellschaftlichen Normen auf Prototypenentwicklung	
Stand der Forschung bzgl. der angewandten Methoden und Technologien	
System-Architektur und Bauweise des Testfahrzeugs (z.B. einteiliges Spritzgussarmaturenbrett im MINI)	
Technologiezyklen der eingesetzten Technologien für die Prototypen (z.B. Flatscreentechnologie)	
Produktzyklen des Testfahrzeugs	
Verfügbarkeit einer Design Guideline	
Reifegrad der angewendeten Prozesse	
Anzahl der Prozessobjekte und -artefakte	
Güte der Durchführung der Aktivitäten	
Grad der Abhängigkeiten zwischen unterschiedlichen Prozessen (z.B. bei Aufteilung in Kleingruppen)	
Grad der simultanen Entwicklung an verschiedenen Prototypen	
Anzahl der Teammitglieder	

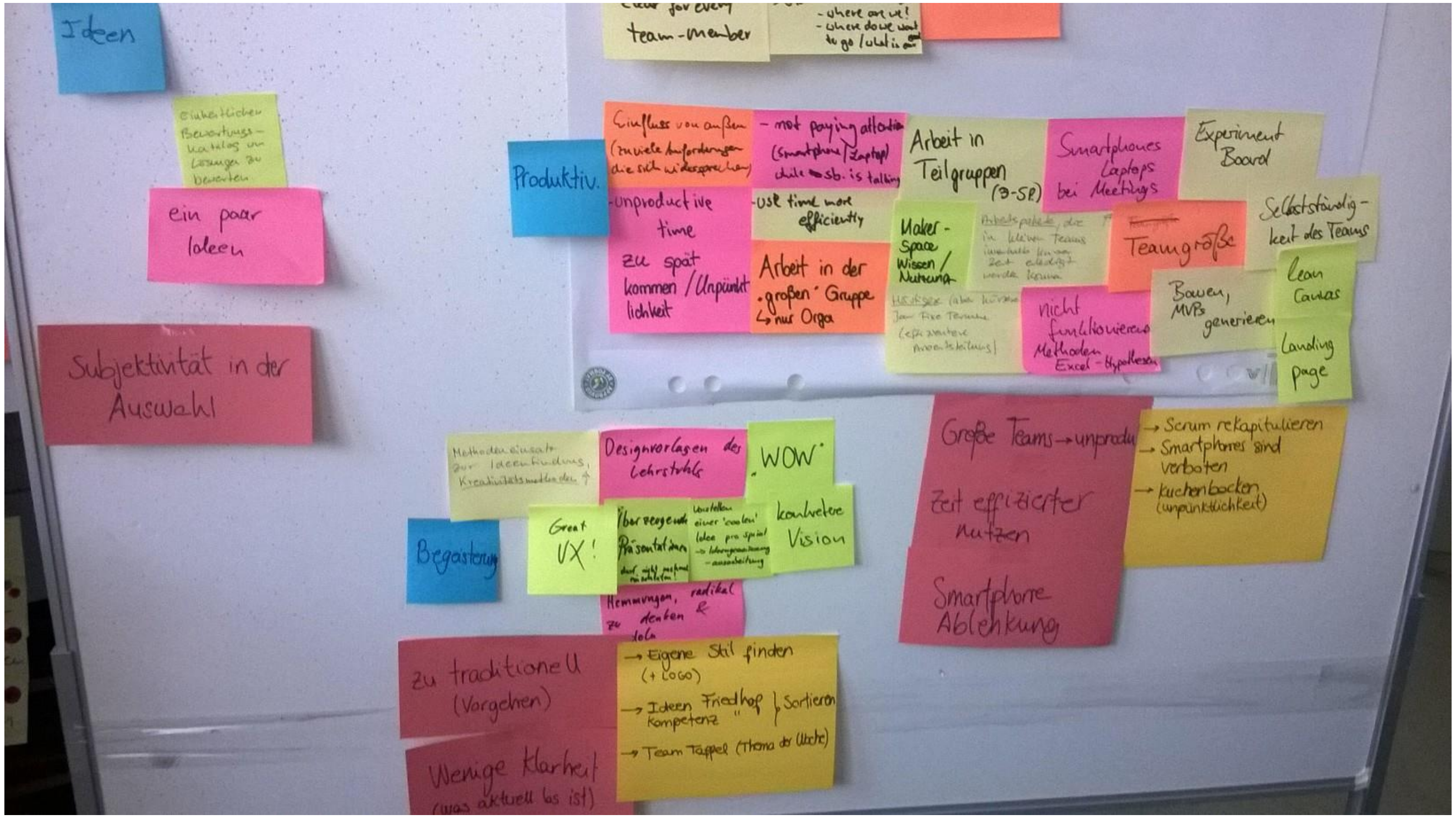
Anzahl der Stunden die Teammitglieder zusammen arbeiten	
Veränderung der Anzahl der Teammitglieder über die Projektdauer	
Vergangene Zusammenarbeit des Teams	
Güte der Zusammenarbeit des Projektteams	
Wissensstand der Teammitglieder bzgl. der Anwendungsdomäne	
Wissensstand der Teammitglieder bzgl. der für die Prototypenentwicklung relevanten Werkzeuge	
Wissensstand der Teammitglieder bzgl. der für die Prototypenentwicklung relevanten Technologien	
Wissensstand der Teammitglieder bzgl. agiler Entwicklung, Design Thinking, Lean Startup	
Einsatz von Entwicklungsmethoden (z.B. Design Thinking)	
Klarheitsgrad der Projektzielvorgabe durch den Lehrstuhl	
Verfügbarkeit der Ansprechpartner des Lehrstuhls (Annette)	
Höhe und Verfügbarkeit des Projektbudgets	
Auswirkungen der Projektdauer von 6 Monaten	
MyMini als studentisches Konstruktions-/Entwicklungsprojekt	
Bedeutung des Projekts für Lehrstuhl und BMW	
Anzahl Stakeholder	
Verfügbarkeit Betreuer, BMW Ansprechpartner, potentielle Nutzer	
Hintergrund Betreuer, BMW Ansprechpartner, potentielle Nutzer	
Verfügbarkeit von Trainingsmöglichkeiten zur Verbesserung der Wissensbasis	
Bereitstellung durch Maker Space	
Verbesserungspotential durch Wissenstransfer von Lehrstuhl, BMW, Netzwerke der Teammitglieder	
Wissensstand der Teammitglieder bzgl. der potentiellen Nutzer im MINI Kontext	
Informationsgebung durch Lehrstuhl	
Trends haben Einfluss auf Ideengenerierung und -bewertung	
Grad zu dem Kundenbefragungen zur Ideengenerierung genutzt werden können	
Grad zu dem Wettbewerberanalysen zur Ideengenerierung genutzt werden können	
Grad zu dem die Gesetzgebung zur Ideengenerierung genutzt werden können	
Grad zu dem die Analyse von Technologie anderer Industrien zur Ideengenerierung genutzt werden können	
Motivation der Projektteilnehmer	
Diversität der Fachrichtungen der einzelnen Teammitglieder	
Offenheit der Teamkommunikation zwischen den Teammitgliedern	
Komplexität des gewählten Prozesses und Zielerwartung	
Grad der Eindeutigkeit der Teammitgliedschaft	
Güte und Natur der Teamführung durch gewählten Teamleiter	
Güte der Sozialkompetenz der einzelnen Teammitglieder	

A3 Analysis of the parameters affecting knowledge reuse

PARAMETERS	RELEVANCY ANALYSIS	
Experience	As the evaluation of the base will only be done among students, it will be considered that experience is in all cases the same, none	✗
Familiarity with the product	Knowing the product will play a role when looking for information. Distinguish between: familiar and not familiar	✓
Type of group work	Being able to change views with coworkers will affect the information needed. Distinguish between: collaborative group and independent working	✓
Location	As the end-user does not know where the knowledge he/she is exactly looking for is, the location parameter doesn´t play a role	✓
Design Phase	Distinguish between: different project phases	✗
Phase of reuse	The knowledge to be reused depends on the 3 types of reuse phases. The information needed in each of them will vary among projects. The impossibility to generalize and the lack of a suitable parameter in our base to organize the information according to this parameter, will force us not to consider it	✗
Type of activity	Depending on the activity carried, the knowledge needed will be different. Distinguish between: beginning of the project or middle-end	✓
Product complexity	Assuming that in a student project all documents contain a similar complexity level, in this base the documents will be only distinguished attending to: general or specific. - Considering the specific documents the ones having a higher complexity level	✓
Purpose	According tot he purpose of the designer the knowledge provided will vary. Distinguish between: innovate or improve an existing solution	✓
Status	As every user in this base environment is a student, the parameter status won't be considered. Furthermore there are no barriers to knowledge in this base	✓
Restriction on time	The time available to study the knowledge does have an impact in the amount and kind of information providing. Distinguish between: having time or not having time	✗

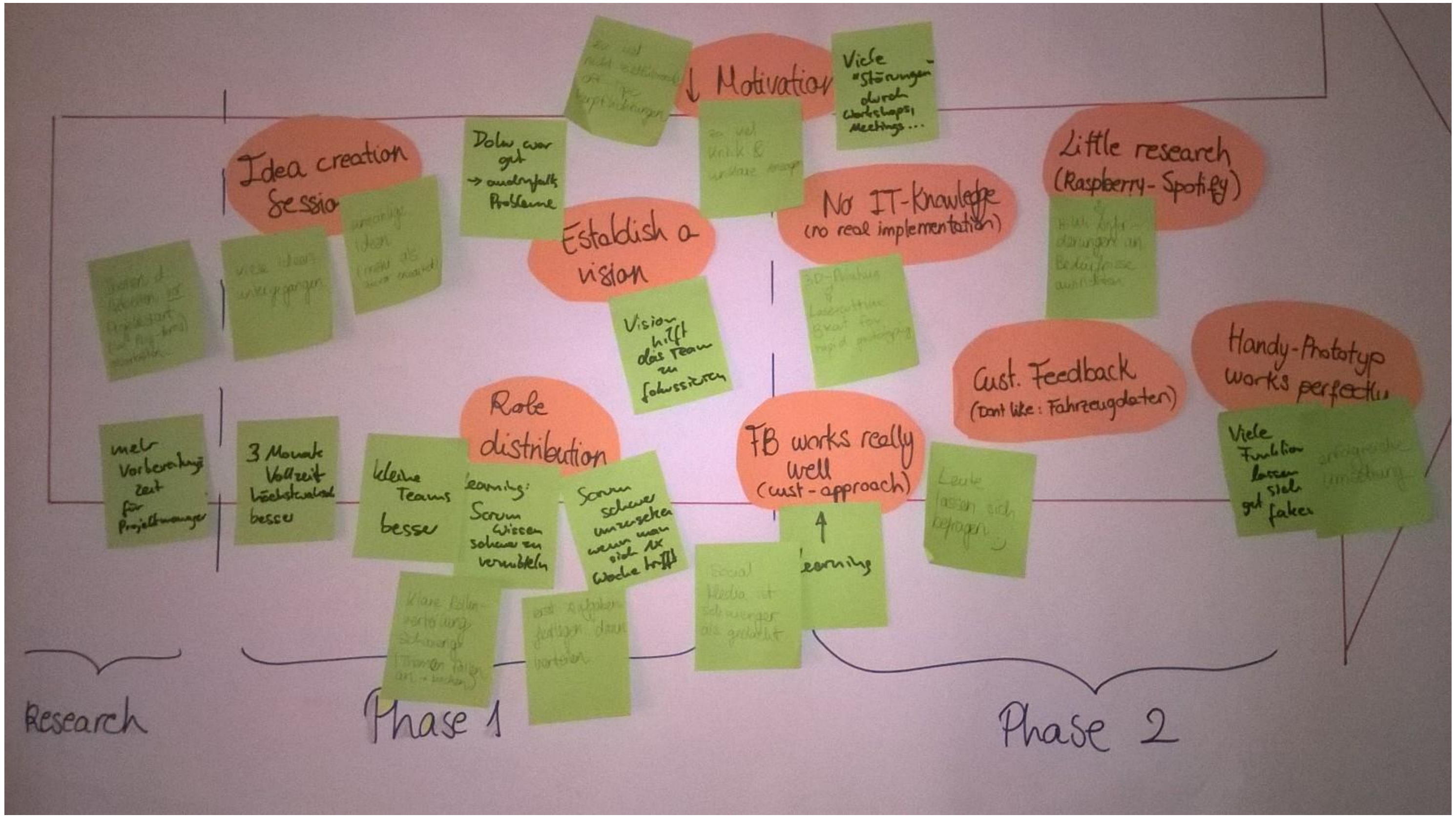
A4 Results A – 1º Lessons learned workshop

A5 Results B – 1º Lessons learned workshop



A6 Timeline Modular –2º Lessons learned workshop

A7 Timeline Modular –2º Lessons learned workshop



A8 Document-registry form

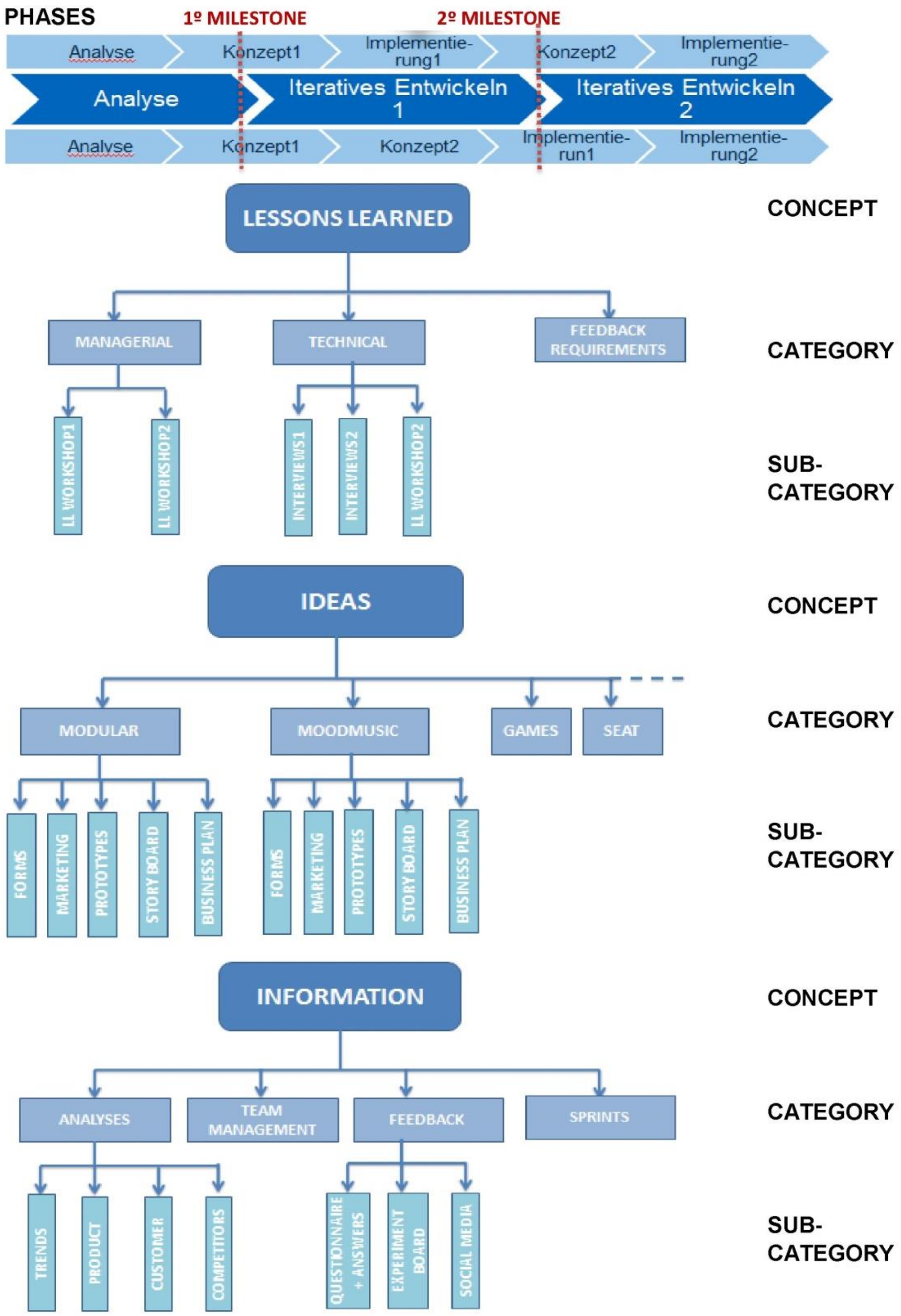
REGISTRATION OF A NEW DOCUMENT IN THE KNOWLEDGE BASE

Document	Name	
	Description	
	Size	
	Status	
	Type	
Registry	Related person	
	Registration date	

	Concept	
Design	Information	
	Ideas	
	Lessons Learned	
	Category	
	Analyses	
	Feedback	
	Team Management	
	Sprint	
	Modular	
	MoodMusic	
	Games	
	Seat	
	App	
	Navi	
	Coffee machine	
	Shopping cart	
	Managerial	
	Technical	
	Requirements	
	Subcategory	
	Trends	
	Product	
	Customer	
	Competitors	
	Questionnaires + Answers	
	Exp. Board	
	Social Media	
	Marketing	
	Forms	
	Prototypes	
	Story Board	
	Business Model	
	LL Workshop1	
	LL Workshop2	
	Interviews1	
	Interviews2	

Phase	
Analyse	
Konzeptphase1	
Konzeptphase2	
Implementierung1	
Implementierung2	
Idea related	
Modular	
MoodMusic	
Games	
Seat	
App	
Navi	
Coffee machine	
Shopping cart	
Subcategory related	
Documents	
Prototypes	
Story Board	
Business Model	

A9 Hierarchies and phases. Registration material



A10 Terms explanation. Registration material

TERMS EXPLANATION

Name	Exact name of the file
Description	Key words regarding the content
Size	See file properties
Status	Choose between: In progress (this IS NOT be the last version of the document) or End
Type	Choose between: Text, PDF, Powerpoint, Excel, Audio, Video, Photo, CAD, Other
Related person	Author of the documents
Registration date	-

Team Management	Team organisation documentation. Not directly project-related
Sprint	Weekly documentation
Managerial	Lessons Learned - Managerial field
Technical	Lessons Learned - Technical field
Requirements	Bernhard Feedback

Trends	Knowledge about trends
Product	Knowledge about the product
Customer	Knowledge about customers
Competitors	Knowledge about competitors
Questionnaires + Answers	Questionnaires, Answers, Feedback evaluation,..
Exp. Board	-
Social Media	Social Media material, posted data, etc.
Marketing	Marketing campaign, Landing Page, etc.
Forms	Formal documentation about an idea. (General. Funtions, Value added, etc.)
Prototypes	Photos, CADs, Videos, idea evolution.
Story Board	Customer Experience Material
Business Model	-

Analyse	From the start to the first milestone (31.05)	
Konzeptphase1	Idea-dependent	
Konzeptphase2	Idea-dependent	*phase 1: 31.05 - 14.07 (2º milestone)
Implementierung1	Idea-dependent	*phase 2: 14.07 (2º milestone) - End
Implementierung2	Idea-dependent	

A11 Usability test. Document registration - Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

2. Ich könnte alle Felder ziemlich schnell ausfüllen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

3. Die Bedeutung der verschiedenen Attributen und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

4. Ich glaube, dass die ausgewählte Attributen das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

5. Alle nötige Attributen wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

-

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	○

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	**2**	**3**	**4**	**Stimme voll zu 5**
○	○	○	○	○

A12 Usability test. Document registration – Person 1

Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

2. Ich könnte alle Felder ziemlich schnell ausfüllen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	X

3. Die Bedeutung der verschiedenen Attribute und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

4. Ich glaube, dass die ausgewählten Attributen das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

5. Alle nötigen Attribute wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

- Idea related war nicht genau einer Idee zuordnenbar

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
X	○	○	○	○

7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	X

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

A13 Usability test. Document registration – Person 2

Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	X	○	○	○

2. Ich ~~könnte~~ alle Felder ziemlich schnell ausfüllen. konnte

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

3. Die Bedeutung der verschiedenen Attribute und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

4. Ich glaube, dass die ausgewählten Attribute~~n~~ das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	X	○	○	○

5. Alle nötigen Attribute wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

-

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
X	○	○	○	○

7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
X	○	○	○	○

A14 Usability test. Document registration – Person 3

Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	☒	○	○

2. Ich könnte alle Felder ziemlich schnell ausfüllen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	☒

3. Die Bedeutung der verschiedenen Attribute und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	☒	○

4. Ich glaube, dass die ausgewählten Attributen das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	☒	○

5. Alle nötigen Attribute wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	☒

-

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	☒	○	○	○

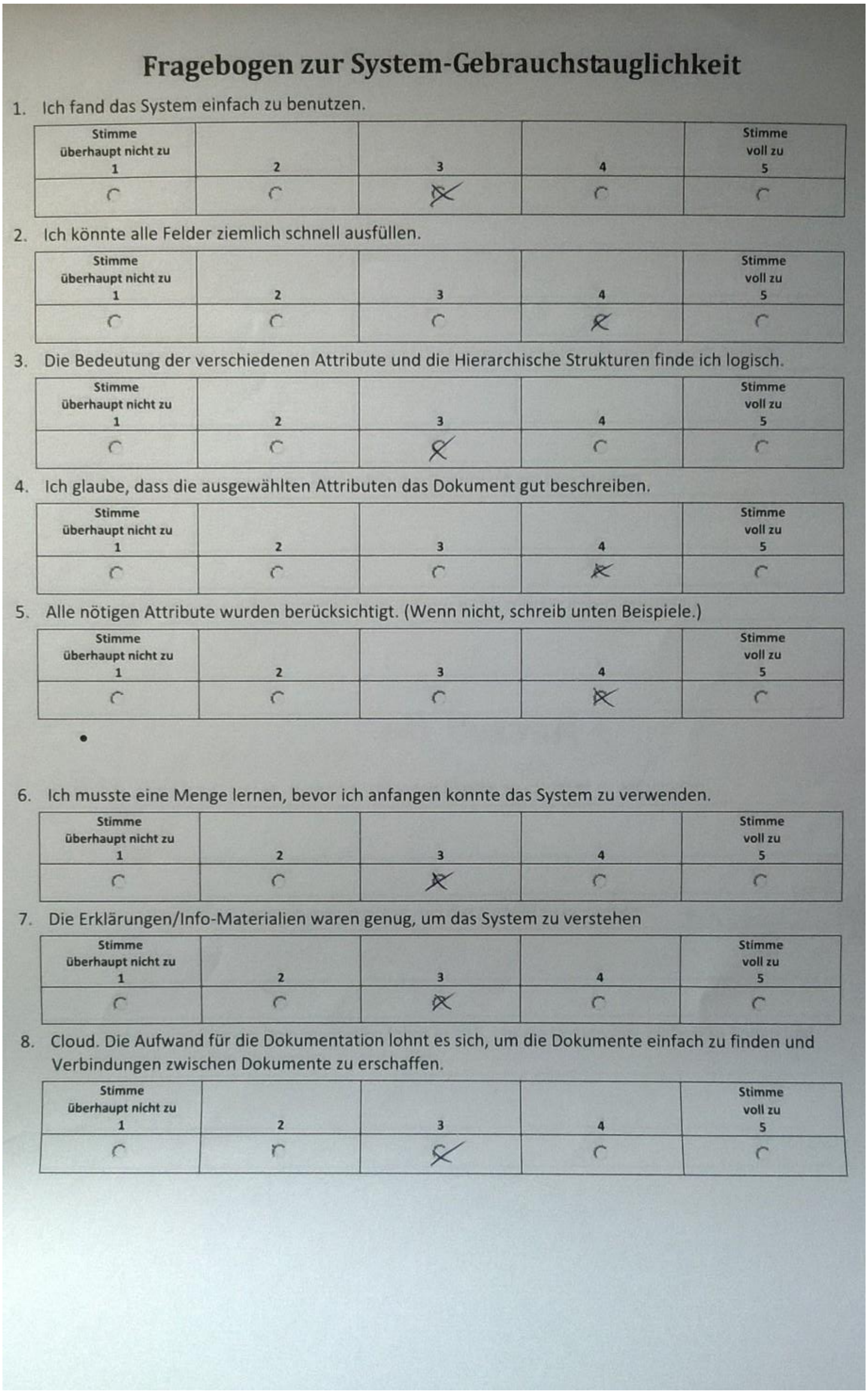
7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	☒	○	○

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	☒	○	○

A15 Usability test. Document registration – Person 4



Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

2. Ich könnte alle Felder ziemlich schnell ausfüllen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

3. Die Bedeutung der verschiedenen Attribute und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

4. Ich glaube, dass die ausgewählten Attributen das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

5. Alle nötigen Attribute wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

-

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

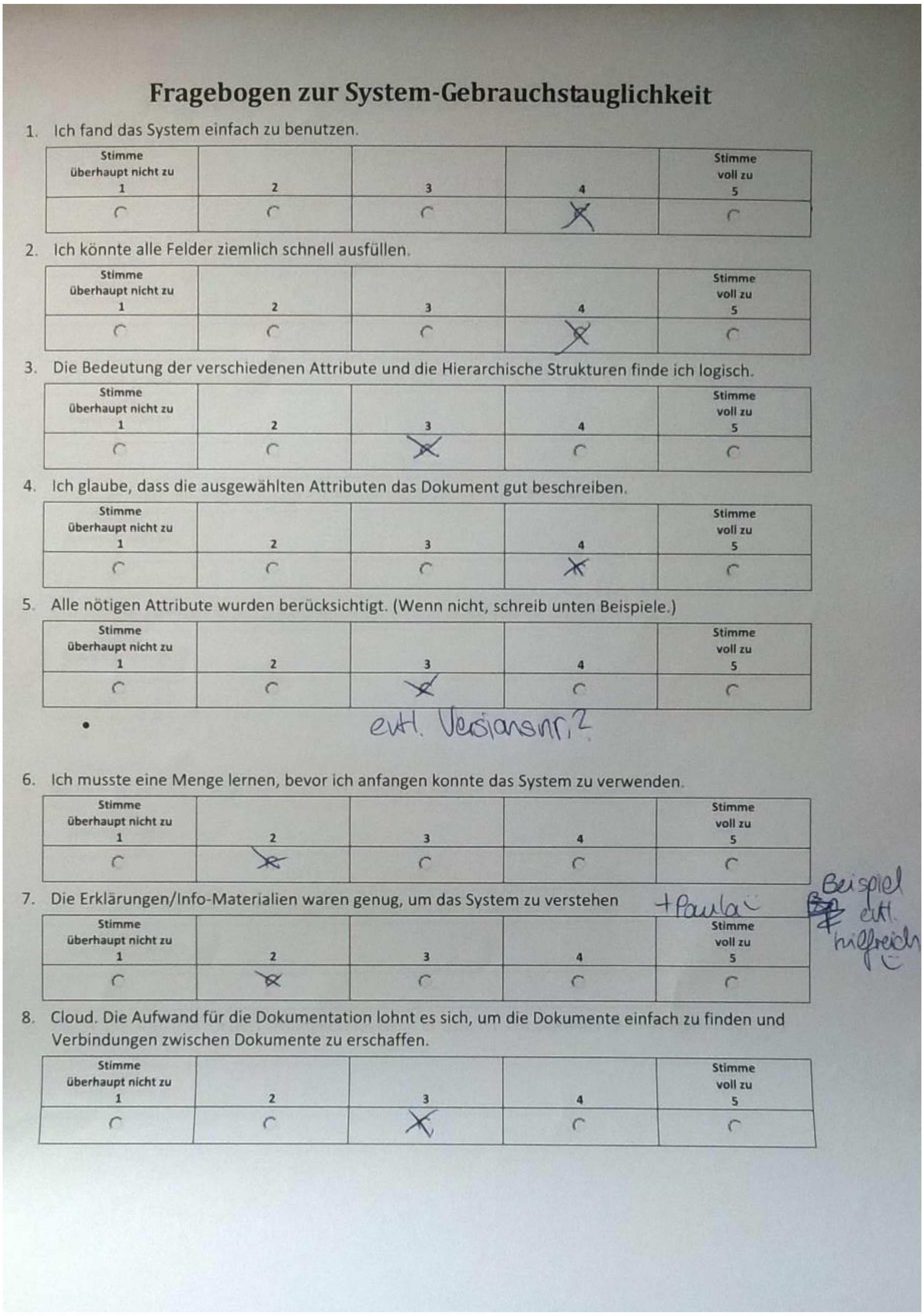
7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

A16 Usability test. Document registration – Person 5



Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
			X	

2. Ich könnte alle Felder ziemlich schnell ausfüllen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
			X	

3. Die Bedeutung der verschiedenen Attribute und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
		X		

4. Ich glaube, dass die ausgewählten Attributen das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
			X	

5. Alle nötigen Attribute wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
		X		

- evtl. Versionsnr.?

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
	X			

7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen +Paula ☺

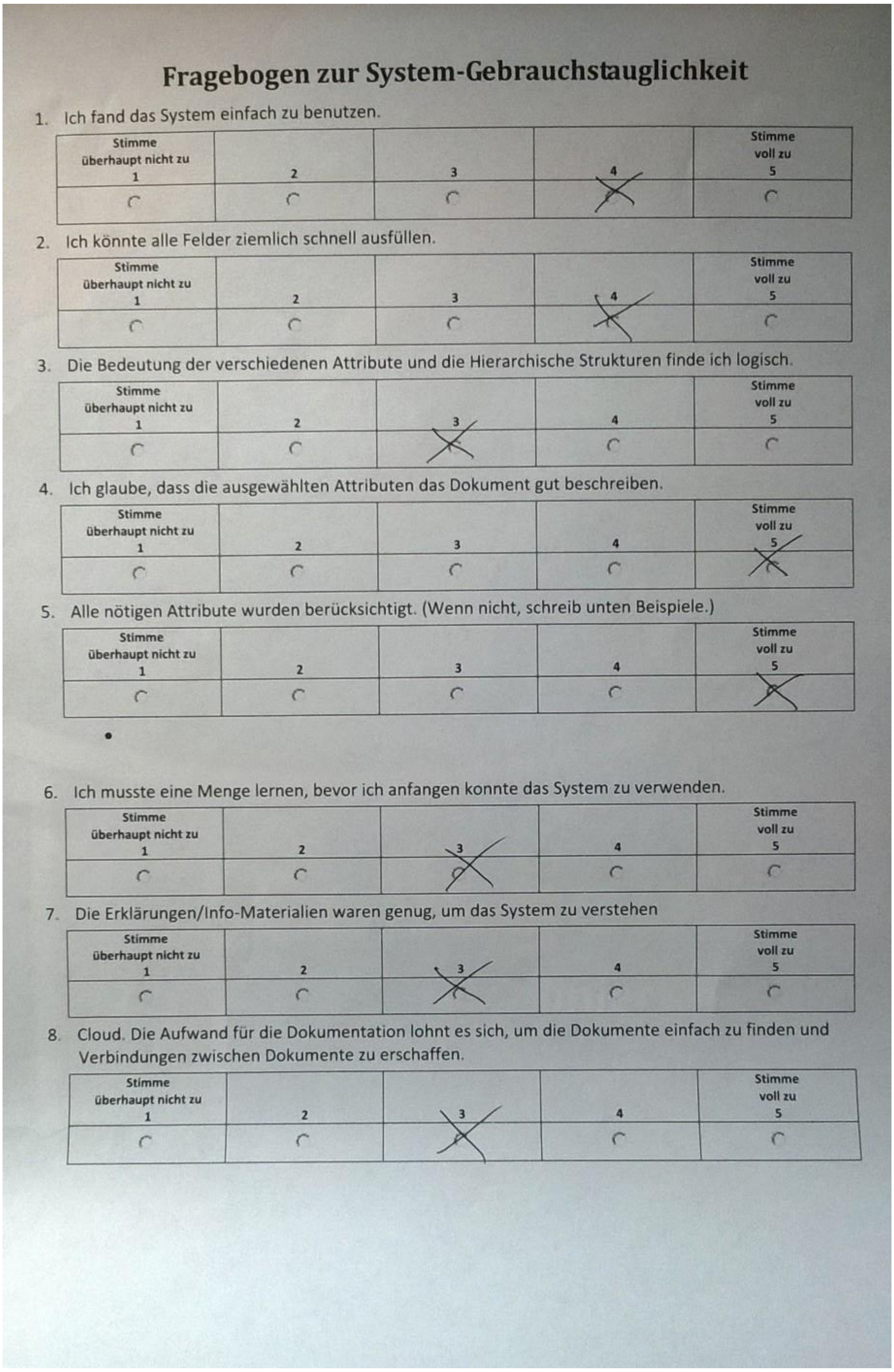
Beispiel evtl. hilfreich ☺

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
	X			

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
		X		

A17 Usability test. Document registration – Person 6



Fragebogen zur System-Gebrauchstauglichkeit

1. Ich fand das System einfach zu benutzen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

2. Ich könnte alle Felder ziemlich schnell ausfüllen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	X	○

3. Die Bedeutung der verschiedenen Attribute und die Hierarchische Strukturen finde ich logisch.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

4. Ich glaube, dass die ausgewählten Attributen das Dokument gut beschreiben.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	X

5. Alle nötigen Attribute wurden berücksichtigt. (Wenn nicht, schreib unten Beispiele.)

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	○	○	X

-

6. Ich musste eine Menge lernen, bevor ich anfangen konnte das System zu verwenden.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

7. Die Erklärungen/Info-Materialien waren genug, um das System zu verstehen

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

8. Cloud. Die Aufwand für die Dokumentation lohnt es sich, um die Dokumente einfach zu finden und Verbindungen zwischen Dokumente zu erschaffen.

Stimme überhaupt nicht zu 1	2	3	4	Stimme voll zu 5
○	○	X	○	○

A18 Cases for the knowledge base usage evaluation

CASE 1:

You have been working as engineer in BMW for the last 10 years in the design department. Since then you have been taking part in almost all projects and therefore you got to know every team member. Moreover, as BMW promotes a strong sharing culture and active communication between team members, you all feel comfortable talking about the problems and solutions that you face during the design. BMW is concerned because the Asia market is innovating much more quickly than they are, so they decided to relieve you from your current tasks, so you can find an innovation that boosts the market.

- Fields to be completed: Familiarity, Purpose, Type of working group, restriction of time, (type of activity, complexity & design phase could also be fulfilled)

CASE 2:

BMW has just employed you as designer. They are concerned about the last design of the middle tunnel their "Modular team" created for their MINI Cooper. Some customers are having problems and they want you to investigate the design and see if there were some mistakes made, so they can be repaired.

- Fields to be complete: Familiarity, Purpose, Type of activity, Complexity. (Modular and Prototype → Help for using the hierarchies)

A19 Usability test. Knowledge base usage evaluation

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	○

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	**2**	**3**	**4**	**Completely agree 5**
○	○	○	○	○

-

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	**2**	**3**	**4**	**Completely agree 5**
○	○	○	○	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

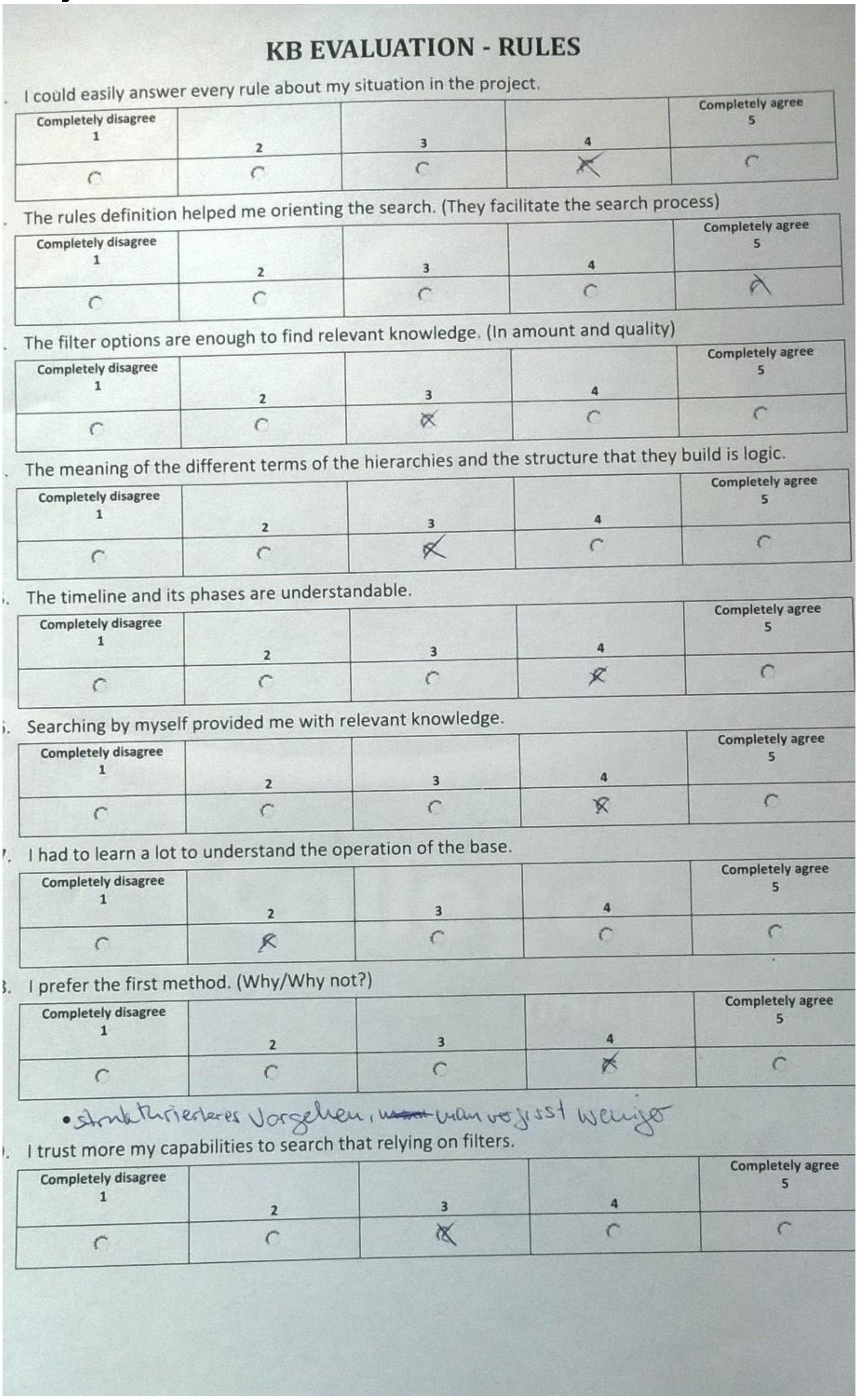
Completely disagree 1	**2**	**3**	**4**	**Completely agree 5**
○	○	○	○	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	**2**	**3**	**4**	**Completely agree 5**
○	○	○	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

A20 Usability test. Knowledge base usage evaluation – Project insider



KB EVALUATION - RULES

I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

- strukturierteres Vorgehen, ~~[illegible]~~ man vergisst weniger

I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	○	x	○	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	x	○	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

- Eher Filter

Eine Kombination

-> erst Hierarchie durchgehen

-> dann Filter festlegen

A21 Usability test. Knowledge base usage evaluation – Project insider

KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

- Es ist leichte verständlich

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

1st: Filtering
if not enough information, then
2nd: search on my own

A22 Usability test. Knowledge base usage evaluation – Project insider

KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

- You don't have the direct control about your search.

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

Sinnvoll Wissensstand der Person miteinzubeziehen
2. Art besser, v.a. wenn Produkt grob bekannt

A23 Usability test. Knowledge base usage evaluation – Project insider

KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
			X	

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
		X		

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
			X	

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
				X

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
				X

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
				X

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
X				

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
	X			

- second more specific

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
	X			

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

erste Methode, sehr umfassend und ~~deckt~~ deckt fast alle relevanten Kriterien ab

A24 Usability test. Knowledge base usage evaluation – Project outsider

KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

• strukturierteres Vorgehen, ~~[illegible]~~ man vergisst weniger

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

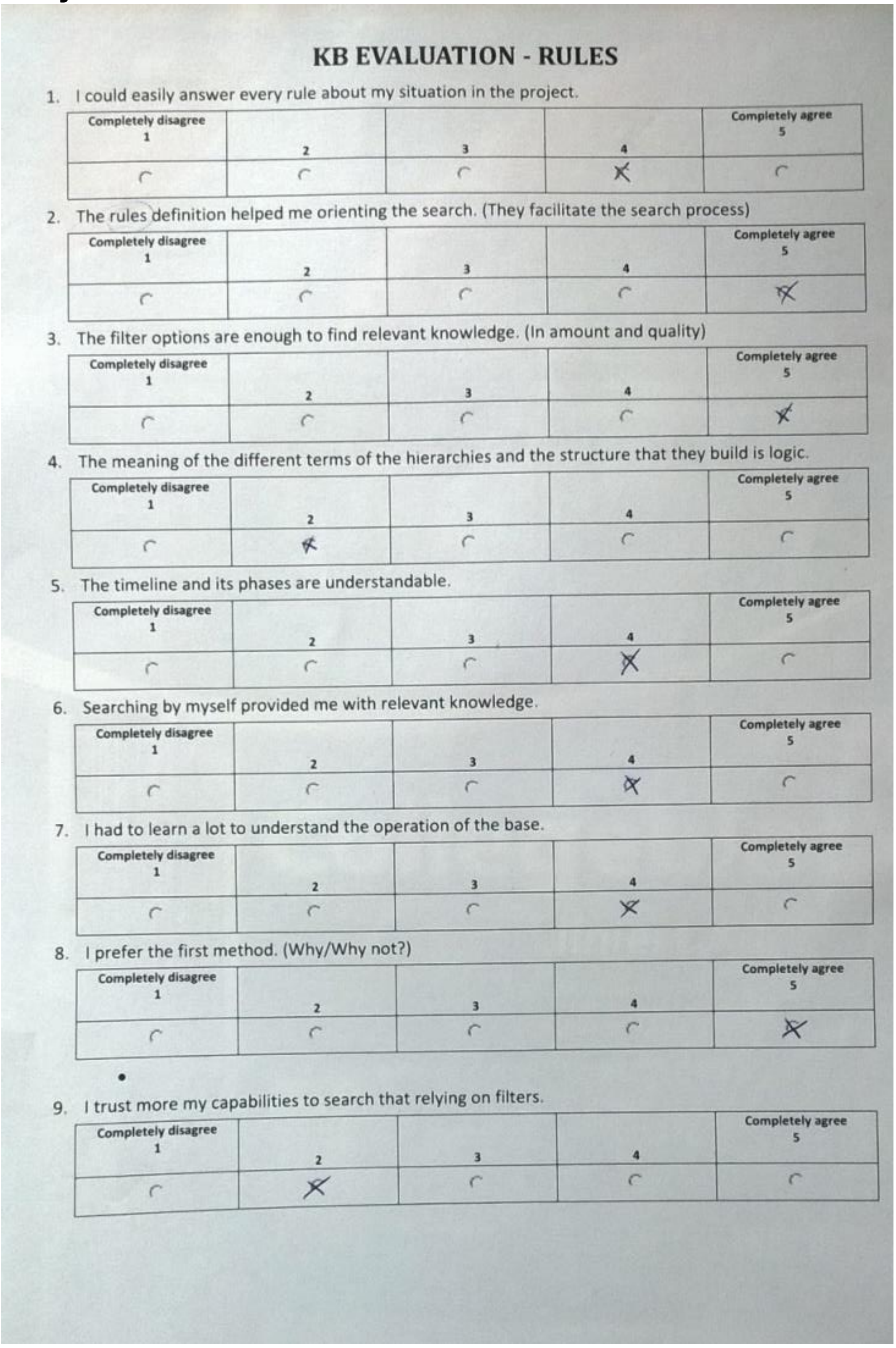
12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

Solución óptima: filtrar primero y luego buscar por jerarquía

→ si poca info → FILTRO MEJOR

→ si mucha info / conocimiento → MEJOR JERARQU

A25 Usability test. Knowledge base usage evaluation – Project outsider



KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

•

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

- Die zweite Methode kann meiner Meinung nach gezielter nach Informationen gesucht werden

A26 Usability test. Knowledge base usage evaluation – Project outsider

KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	X	○

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	○	X

•

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	X	○	○	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	○	X	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

Keywords, automatic filtering by relevance

blind filters are also an amazing possibility

A277 Usability test. Knowledge base usage evaluation – Project outsider

KB EVALUATION - RULES

1. I could easily answer every rule about my situation in the project.

Completely disagree 1	2	3	4	Completely agree 5
		X		

2. The rules definition helped me orienting the search. (They facilitate the search process)

Completely disagree 1	2	3	4	Completely agree 5
	~~X~~		X	

3. The filter options are enough to find relevant knowledge. (In amount and quality)

Completely disagree 1	2	3	4	Completely agree 5
	~~X~~		X	

4. The meaning of the different terms of the hierarchies and the structure that they build is logic.

Completely disagree 1	2	3	4	Completely agree 5
~~X~~				X

5. The timeline and its phases are understandable.

Completely disagree 1	2	3	4	Completely agree 5
~~X~~				X

6. Searching by myself provided me with relevant knowledge.

Completely disagree 1	2	3	4	Completely agree 5
	~~X~~		X	

7. I had to learn a lot to understand the operation of the base.

Completely disagree 1	2	3	4	Completely agree 5
	X		~~X~~	

8. I prefer the first method. (Why/Why not?)

Completely disagree 1	2	3	4	Completely agree 5
	X			

•

9. I trust more my capabilities to search that relying on filters.

Completely disagree 1	2	3	4	Completely agree 5
			X	

10. On a daily work as a designer, I think that using the hierarchies is more time effective than following the proposed rules.

Completely disagree 1	2	3	4	Completely agree 5
○	○	○	☒	○

11. From my past experiences I can tell that the knowledge you get from filtering is normally little relevant or inaccurate.

Completely disagree 1	2	3	4	Completely agree 5
○	☒	○	○	○

12. Did any of the search options proposed satisfied your way of searching for information? How would you have approached such a search?

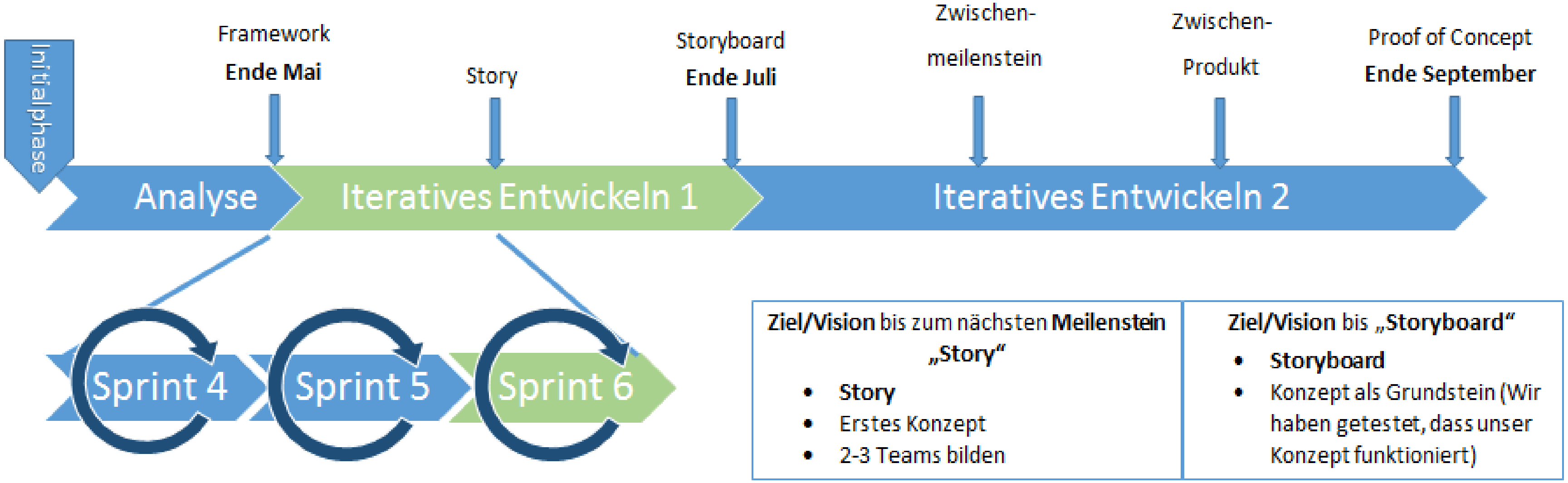
Second option showed good results.

Combination of search with filters and "open" search to find information I did not initially think about.

Maybe provide even more specific filters like „storyboard", etc.

A28 Example of a Sprint document

Sprint 6: von 15.6. – 14.7.



Stimmung = Team Stimmung   Modular = Team Modulare Konsole

Personen: Bernhard(B), Benjamin(Ben), Christian(C), Manuel(M), Max(Max), Moritz(Mo), Paula(P), Sebastian(S), Theresa(T), Florian(F)

Ziele in diesem Sprint: Wie war die Zielsetzung des Sprints?
Alle:
Stimmung: Kunden finden, wie Kunden erreichen, Killer feature herausfinden, Wettbewerb recherchieren
Modular: Grob- und Feindefinition des Konzeptes, bessere Vorstellung von der technischen Machbarkeit
Persönliche Ziele:

Methoden in diesem Sprint: Welche Methoden haben die Teams eingesetzt?
Alle:
Stimmung: Recherche, Statista
Modular: Internetrecherchen, Analysen, Brainstorming

Aufgetretene Probleme: Welche Probleme sind während des Sprints aufgetreten?
Alle:
Stimmung: Spotify im Auto gibt es in ähnlicher Form
Modular: Detaillierte Informationen über verbaute Elektronik schwer auffindbar

Besondere Erkenntnisse/Learnings Welche Erkenntnisse konnten aus dem Sprint gezogen werden?
Alle:
Stimmung: Wir müssen uns differenzieren, Mini Nutzer ist wirklcih 50, auch alte sind in Foren, junge wahrscheinlich eher auf facebook
Modular: Fokussierung auf neue Technologien/Geräte/Devices, die ins Auto mitgebracht werden

Ingenieurstechnische Fragestellungen: Welche technischen/methodischen Fragen sind bei der Umsetzung aufgetreten?
Stimmung: -
Modular: Noch keine - -

Ingenieurstechnische Lösungen Wie konnten die technischen/methodischen Fragen beantwortet werden?
Stimmung: - - -
Modular:- Noch keine - -

Verwendete Informationen: Welche Informationen konnten zur Umsetzung genutzt werden?	Quelle	Information
Alle:		
Stimmung:	Statista, Foren, Facebook, Internet	Über Kunden und Wettbewerb
Modular:	Internet	Aktuelle Schnittstellen in Fahrzeugen

Gewünschte Informationen:	Information Welche Informationen hätten geholfen die Umsetzung schneller/besser zu gestalten?
Alle:	
Stimmung:	Mehr Infos von BMW zu Kunden
Modular:	Blick in die Glaskugel, was sind die Trends der Zukunft, welche Schnittstellen werden diese haben/benötigen

Fortschritt	Wie hoch schätzen Sie den bisherigen Projektfortschritt (0=Anfang; 100=vollkommene Erreichung der Ziele?
Stimmung:	55
Modular:	55

Positive Einflussfaktoren: Welche Faktoren (z.B. Teamgröße, Wissen über Methoden, Ressourcen) haben den Projektfortschritt in diesem Sprint gefördert?
Alle:
Stimmung: Statista, kleine Teams, Aufgabenteilung
Modular:Teamgröße, Aufgabenaufteilung

Negative Einflussfaktoren Welche Faktoren (z.B. Teamgröße, Wissen über Methoden, Ressourcen) haben den Projektfortschritt in diesem Sprint behindert?
Alle:
Stimmung: Demotivation durch wettbewerbsanlayse
Modular: Verschiedene Vorstellungen vom Konzept

Bericht (was bisher nicht erwähnt wurde):

<Allgemein>

Stimmung:

Modular:

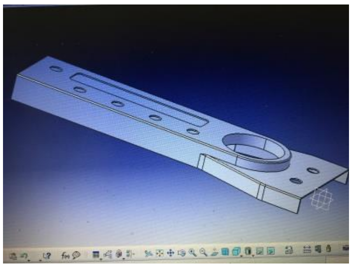
A29 Example of an Idea Form document

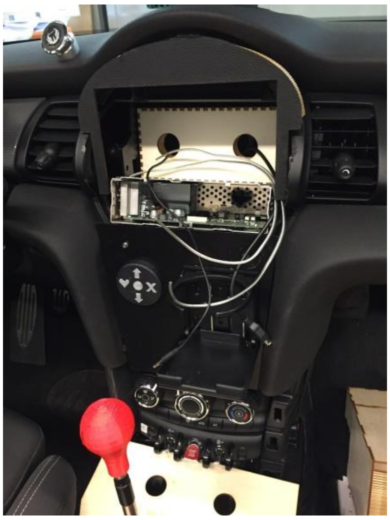
<u>3º Meilstein → Dokumentation für die Wissensbasis</u>

Idee: MyMINI.concept

Produkt:

- **Fotos/Skizzen/CAD + (Maßen)**






- **Kürze erklärung → Warum ist das interessant für den Kunden? (Kundennutzen)**
- Kunde hat mehr Möglichkeiten sich sein Fahrzeug zu individualisieren und insbesondere seinen Bedürfnissen und Gewohnheiten anzupassen
- **Funktion + Verhalten**
- MyMINI.concept bietet Steckplätze an mehreren Stellen im Fahrzeug (I-Tafel, Mittelkonsole, Handschuhkasten), um dem Kunden die Möglichkeit zu bieten, seine Module nach seinen Bedürfnissen anzuordnen. Zudem können auf einer Magnettafel in der I-Tafel einige Module komplett frei angeordnet werden.

Prozess:

- **Materialien**
- Protoyping mit unterschiedlichen Materialien: erste Prototypen (Handschuhkasten) mit Holz zur schnellen Umsetzbarkeit; I-Tafel (magnetisch) aus Stahl für freie Platzierung der Module; Mitteltunnel erst in 3D-Druck geplant, dann jedoch aus Kosten- und Zeitgründen aus Holz gecuttet; finaler Modulsteckplatz bei Handschuhkasten aus Holz mit Leder überzogen

- Auch Modul-Prototypen aus unterschiedlichen Materialien: Holz, 3D-Druck
- **Konstruktiv Prozess (3D, Laser,..)**
- **Einschränkungen und Spezifikationen (Verbesserungen vs. vorherige Prototypen und begründung, warum diese Lösung ausgewählt wurde)**
- Schrittweises Ausweiten des Individualisierungsraumes: zunächst Konzept mit modularem Handschuhfach, dann Hinzuziehen der I-Tafel und zum Schluss der Mittelkonsole
- Dadurch mehr Möglichkeiten zur individuellen Platzierung
- Ursprüngliche Idee Bedienelemente frei anordnen zu können wurde verworfen auf Grund von Kundentests → Interaktion mit Fahrzeug nur über einen großen Touchscreen gewünscht
- Beschränkung auf Hardware-Module und Darstellung der einfachen Austauschbarkeit um unterschiedliche Lebenszyklen in Einklang zu bringen

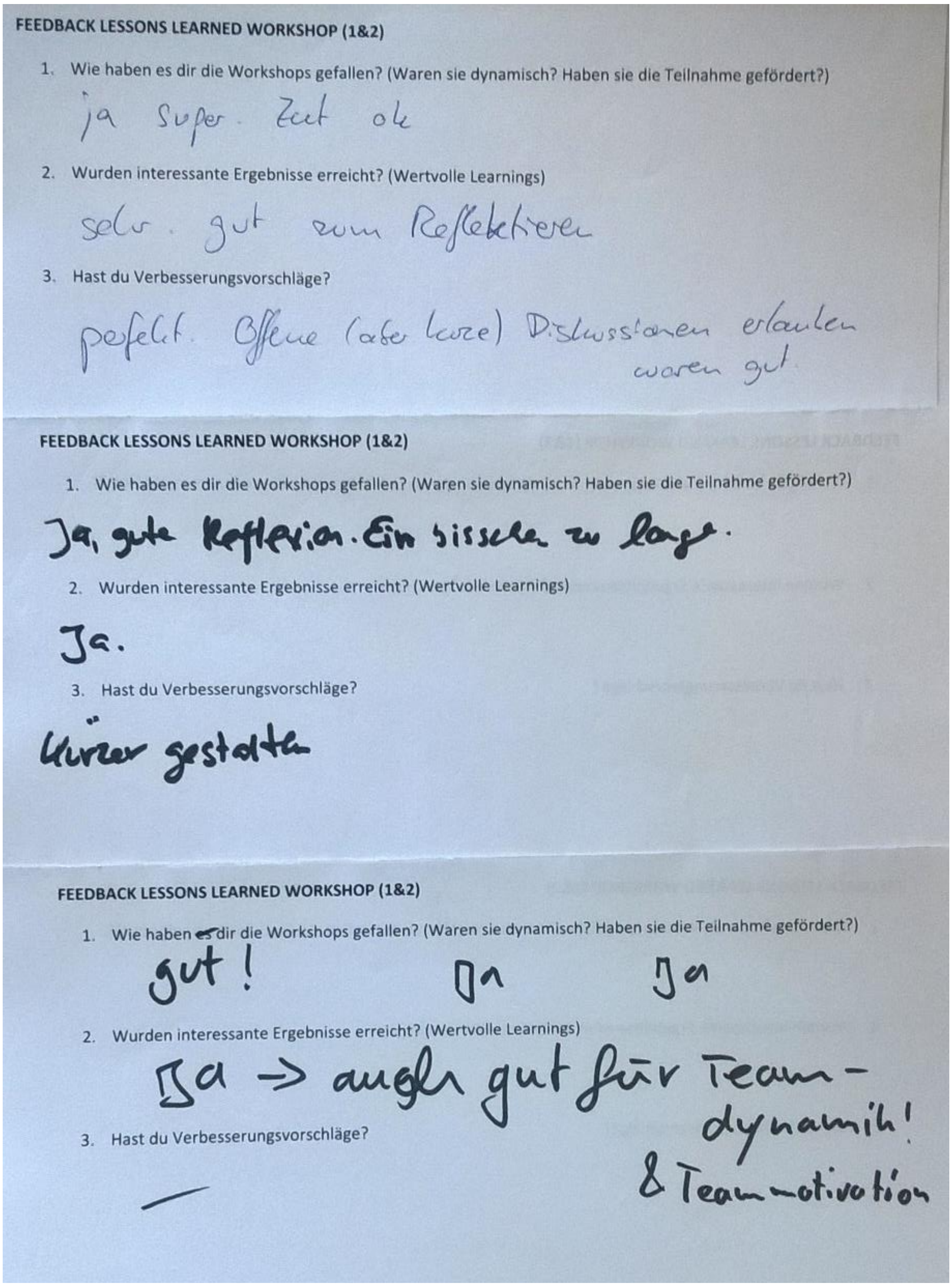
Sonstige:

Alle Informationen über das Produkt, Prozess oder etwas anderes, dass für einen zukünftigen Nutzer der Basis interessant sein könnte. (Nicht, dass sie die gleiche Fehler begehen oder , dass sie die Begründung der aktuelle Lösung nicht verstehen)

Frühzeitig beginnen die Idee prototypisch umzusetzen, damit man es dem Kunden zum Ausprobieren geben kann. Nutzer von Produkten (insbesondere Automobil) sind sehr unkreativ, haben geringes Vorstellungsvermögen und finden sich mit dem ab, was sie von den Herstellern vorgesetzt bekommen. Um jedoch von einer neuen Idee zu überzeugen, muss es für den Kunden erlebbar gemacht werden, damit dieser auch evtl. auf neue Ideen kommt und konstruktives Feedback geben kann.

Vision mit konkreten Zielen für den Prototypen aufstellen, damit man ein festes Ziel hat, worauf man hinarbeitet und genau weiß, was man mit diesem Prototypen erreichen möchte.

A30 Feedback from the participants of the lessons learned workshops



FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben es dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

   ja super. Zeit ok

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

   sehr gut zum Reflektieren

3. Hast du Verbesserungsvorschläge?

   perfekt. Offene (aber kurze) Diskussionen erlauben waren gut.

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben es dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

   Ja, gute Reflexion. Ein bisschen zu lange.

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

   Ja.

3. Hast du Verbesserungsvorschläge?

   Kürzer gestalten

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben ~~es~~ dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

   gut! Ja Ja

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

   Ja → auch gut für Team-dynamik! & Teammotivation

3. Hast du Verbesserungsvorschläge?

   —

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben es dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

Gut, haben geholfen Probleme und positive Aspekte d. Projektes aufzuzeigen

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

Nein, die meisten waren schon bekannt.

3. Hast du Verbesserungsvorschläge?

Super

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben ~~es~~ dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

Sehr gut. Sympatische Workshop Leiterin. Ja, dynamisch. Ja, Teilnahme wurde gefördert!

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

Ja!

3. Hast du Verbesserungsvorschläge?

Nein.

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben es dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

gut, wurde zur Mitarbeit angeregt

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

guter Austausch von Meinungen

3. Hast du Verbesserungsvorschläge?

vor dem Workshop Agenda geben zur Orientierung

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben es dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

- Gutes Resümee der vergangenen Monate
- Bewusstmachen der Ergebnisse

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

- Projektmanagement anders gestalten
- verteilte Kompetenzen wichtig

3. Hast du Verbesserungsvorschläge?

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben es dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

☺ gut Selbstreflexion über Team Orga... gefördert

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings) Gefühl negatives nicht umgesetzt ↔ nächste Projekte profitieren

Ja, v.a. Teil 1 ⇒ Umsetzung im Projekt. Hoffe Teil 2 hilfreich für kommende Projekte :)

3. Hast du Verbesserungsvorschläge?

zum Workshop nein

FEEDBACK LESSONS LEARNED WORKSHOP (1&2)

1. Wie haben ~~es~~ dir die Workshops gefallen? (Waren sie dynamisch? Haben sie die Teilnahme gefördert?)

Waren ganz okay.

2. Wurden interessante Ergebnisse erreicht? (Wertvolle Learnings)

Ich weiß nicht, ob die Diskussionen vll zu sehr vom Thema abgedriftet sind

3. Hast du Verbesserungsvorschläge?

Manchmal fand ich es schwer zu verstehen, was genau gemacht werden soll

DOCUMENT 2: BUDGET

Table of content

- Labor costs
- Software licenses
- Material costs
- Transport costs
- Indirect costs and taxes
- Budget summary

BUDGET

For the development of this project some expenditure were incurred. These include among others: labor costs, software licenses, material expenses and transport costs.

Labor costs:

In the design of this knowledge base a junior engineer and a senior one, both of the mechanical specialization were involved. The junior one worked on full-time basis; and the senior one, as a sporadic consultant. The salaries of both were calculated according to the average wages been paid in Spain for these level of qualification in the year 2016. In case of the junior engineer 9 € per hour were assumed, being 10,5 € per hour considered for the senior one. For the evaluation phase, twelve volunteers were required. These were distinguished between engineers and students, considering if they had been involved in the project (and therefore had some topic related experience) or not. For this purpose we considered the remuneration of the engineers being as well 9 € per hour, while the one for the other students being 6 € per hour.

Labor Costs	Amount	Time invested	Cost	TOTAL*
Junior Mechanical Engineer	1	1000 h	9 €/h	9.000 €
Senior Mechanical Engineer	1	24 h	10,5 €/h	252 €
Volunteers - Students	4	1 h	6 €/h	24 €
Volunteers - Junior Engineers	8	1,5 h	9 €/h	108 €
TOTAL*				9.384 €

* Taxes are not applied

Software licenses:

To implement the knowledge base a given software was required. In this case, Soley offered a free trial, so no costs were incurred. On the other hand, to effectively write the memories of this work, a second software was used. Citavi is a tool to comfortably enter citations and references. This had a cost of 199 € for a whole year license.

Software Licenses	Amount	Cost	TOTAL*
Soley License	1	-	-
Citavi License	1	199 €	199 €
TOTAL*			199 €

* Taxes are not applied

Material costs:

To support the Lessons Learned Workshops, office material were needed. Here cardboards, paintings, printings and other plastic materials were provided. The costs of all of them sum up to 35 €. Also for this purpose, two GoPro cameras were rented. The price of each for the whole day was 15 €.

Material Costs	Amount	Cost	TOTAL*
Office Material	1	35 €	35 €
Rental - GoPro Camera	2	15 €	30 €
TOTAL*			65 €

* Taxes are not applied

Transport costs:

Additionally, transport costs had to be recognized, as the office was located on the outside of the city, which implied a 50-minute ride by metro. The subway seasonal ticket price amounted to 170 €.

Transport Costs	Cost	TOTAL*
Subway season ticket	170 €	170 €
TOTAL*		170 €

* Taxes are not applied

Indirect costs and taxes:

Considering all the above, the costs of the project before taxes ascended to 9.818 €

Concept	Cost
Total of labor costs	9.384 €
Total of software licenses	199 €
Total of material costs	65 €
Total of transport costs	170 €
TOTAL*	9.818 €

* Taxes are not applied

Due to the nature of the project, some indirect costs were charged as well. These represent a 6% of the just calculated amount.

Indirect costs 6%	589 €

Considering the taxes being a 21%, the total budget to be able to efficiently run the project can be seen in the following table.

Total costs	10.407 €
Taxes 21%	2.185 €
TOTAL after taxes	12.592 €

Regarding all these expenses, the final costs of the project reached an amount of approximately 12.600 €, being the labor costs the most meaningful ones.

Budget summary:

	Concept	Amount	Time invested	Cost	TOTAL*
Labor costs	Junior Mechanical Engineer	1	1000 h	9 €/h	9.000 €
	Senior Mechanical Engineer	1	24 h	10,5 €/h	252 €
	Volunteers - Students	4	1 h	6 €/h	24 €
	Volunteers - Junior Engineers	8	1,5 h	9 €/h	108 €
Software licenses	Soley License	1	-	-	-
	Citavi License	1	-	199 €	199 €
Material costs	Office Material	1	-	35 €	35 €
	Rental - GoPro Camera	2	1	15 €	30 €
Transport costs	Subway season ticket	1	-	170 €	170 €
Indirect costs	Indirect costs	6%	-	-	589 €
	Total costs*	-	-	-	10.407 €
	Taxes	21%	-	-	2.185 €
	TOTAL COSTS	**12.592 €**			