Implementation And Evaluation Of The
Knowledge Element Preparation Model

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Abstract

The starting point for this thesis is the Knowledge Element Preparation Model (KEP Model) developed by Thalmann (2012). The KEP Model supports a decision maker to answer the following question: Which knowledge elements should be prepared according to which adaptation criteria by whom? Guided by a design science research approach this work applies and evaluates the KEP Model in a real world scenario in the EU FP7 Learning Layers project. This requires an implementation of the KEP Model—the KEPTool. For the application suitable data sets were collected and input ratings for the KEPTool were gathered with a survey and expert interviews. This enables the computation of a proposal, which serves as input to the consecutive evaluation of the KEP Model and the KEPTool. Therefore, interviews were conducted with experts from the Learning Layers project to evaluate the proposal, the factors and weights in the KEP Model, the rating procedure and to identify requirements for the graphical user interface and future application scenarios for the KEPTool.
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This work is dedicated to Bettina.
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1 Introduction

Every day many videos, wiki pages, pictures, figures, texts, and presentations are created. Such knowledge elements may be authored, for example, in social software platforms, in the context of an organisation, or in a project. Now, these created knowledge elements may be developed and adapted for further use and different users. This raises the questions: Which of the knowledge elements should be selected for further preparation? How can decision makers balance the expected benefits and the efforts of such a preparation? The Knowledge Element Preparation Model (KEP Model) has been developed to answer these questions. It supports a decision maker to find knowledge elements, which are best suitable for preparation according to different adaptation criteria (Thalmann, 2012). Thalmann (2012, p. 312) states as future work the application of the KEP Model in a real world context. That serves as starting point for this thesis. The aim is to apply the KEP Model in a real world context: The Layers Theory Camp. The Layers Theory Camp is part of the the Learning Layers (LL) project\(^1\).

The KEP Model supports a decision maker to decide which knowledge elements should be selected for preparation. Thus, it forms the basis for a decision support system (DSS). DSSs deal with semi-structured and unstructured problems, as opposed to structured and less critical problems, where automation is more feasible (Hosack et al., 2012, p. 317). DSSs typically support the solution of problems and evaluate opportunities (Turban et al., 2011, p. 75). The decision maker, provides the human intellect and the expertise for the development and use of a DSS (Turban et al., 2011, p. 107). DSSs have to evolve, i.e., they have to be replanned, modified, expanded, and improved, which is triggered by the user’s experience with the system (Kim and Guimaraes, 1992, p. 29).

The evaluation of a DSS is crucial for its evolution to progress in the desired direction (Kim and Guimaraes, 1992, p. 29). The thorough examination of a DSS allows to find out whether the system works well, the advice is sound, and it addresses the users’ needs (Papamichail and French, 2005, p. 84). Further, the evaluation of

\(^1\)See learning-layers.eu.
a created artefact provides feedback information and a better understanding of the problem to improve the quality of the artefact and the design process (Hevner et al., 2004, p. 78).

**Formative evaluation** is performed iteratively during the development process of a DSS until weak points are eliminated and the objectives are reached (Rhee and Rao, 2008, p. 319) and is intended to provide directions for continuing development (Leroy, 2011, pp. 204). It is beneficial to evaluate a DSS early on in the development process, where changes are relatively easy and inexpensive to incorporate (Adelman, 1992, p. 5).

Academics evaluate their developed DSSs to document quality of their scholarly contribution for publication purposes (Pick and Weatherholt, 2013, p. 9). Researchers need to demonstrate the utility and quality of a design artefact. Therefore, a crucial aspect of research is evaluation (Hevner et al., 2004, p. 85). However, in a literature review of DSSs, Arnott and Pervan (2012, p. 935) established, that more than 40% of designed artefacts solely consist of a presentation and description without the attempt to establish the artefact’s worth, effectiveness or usefulness. They conclude, evaluation is the “biggest weakness in DSS design science research” (Arnott and Pervan, 2012, p. 938).

Rhee and Rao (2008, p. 313) identify a gap between the interest about the evaluation of a DSS from a scholar’s and a practitioner’s perspective. Whereas the scholar’s goal is to gain insight for later use, the ultimate goal for practitioners is to improve the DSS and the performance of the decision-making process. But, researchers need to select problems considering the professional relevance and interest (Arnott and Pervan, 2008, p. 667). Highly abstract representations are blamed with having no relationship to the real world (Hevner et al., 2004, p. 99).

This thesis aims at both, the academic’s and practitioner’s perspective. The **KEP Model** is to be implemented and evaluated in a real world context. As already suggested by Thalmann (2012, p. 312) a research gap is identified—the application and the evaluation of the **KEP Model**. To apply the **KEP Model**, in the context of the Layers Theory Camp, it will be implemented leading to the **KEPTool**. Thus, the research objective of this thesis is:

**Research Objective:**
The implementation and formative evaluation of the **KEP Model** and the **KEPTool**.

This research objective is divided into six sub-objectives. These sub-objectives are concerned with evaluating the output of the **KEPTool** (sub-objective 1), the factors...
and weights of the KEP Model, the rating procedure for the factors (sub-objectives 2-4), and the future directions for the development of the KEPTool (sub-objectives 5-6). In the following, the six sub-objectives are stated. These statements are succeeded by a description of the expected results.

• **Sub-Objective 1:** Evaluation of the proposal the KEPTool computed for the Layers Theory Camp. This aims at the evaluation of the output, i.e., the proposal computed by the KEPTool. The potential users are expected to agree or disagree with the proposal and their reasoning is expected to show directions towards the improvement of the KEP Model and the KEPTool.

• **Sub-Objective 2:** Evaluation of the factors influencing the benefits and efforts in the KEP Model. This aims at the investigation of the individual factors influencing the benefits and efforts in the KEP Model. Further potential factors, or aspects of factors, which could be incorporated in the KEP Model, could be identified.

• **Sub-Objective 3:** Evaluation of the weights balancing the factors in the KEP Model. This aims at the validation of the necessity of weights in the KEP Model, i.e., to determine, whether the users assign different weights to individual factors of the KEP Model. Further, it is expected to record reasoning as to how the weights may be instantiated by the users.

• **Sub-Objective 4:** Evaluation of the rating procedure of the factors influencing the benefits in the KEP Model. This aims at gaining insight on how the users performed the ratings for the benefits of the KEP Model. Their reasoning is expected give directions on how to improve and further facilitate the rating procedure.

• **Sub-Objective 5:** Identification of requirements on the graphical user interface of the KEPTool. This aims at identifying specific requirements on the graphical user interface for the KEPTool.

• **Sub-Objective 6:** Identification of further application scenarios of the KEPTool. The users will be presented with the application of the KEPTool for the Layers Theory Camp. However, it is expected, that they could give insight into further and different application scenarios. Further, the aim is to identify the user’s reasoning on potential benefits, which could result from the application of the KEPTool in their identified scenarios.
Finally, Figure 1.1 gives an overview of the tasks of this thesis. In the centre of the figure, the overall research objective is stated. The arrows indicate dependencies between the tasks. The activities related to the (sub-)objectives are distinguished by a grey background.

This thesis is structured as follows: Chapter 2 gives the foundations of the thesis. First the KEP Model is introduced in Section 2.1 and related to design science research in Section 2.2. The KEP Model as a decision support systems is discussed in Section 2.3, and Section 2.4 reviews the evaluation of decision support systems. A summary and implications for the next chapters are given in Section 2.5. Chapter 3 describes the implementation of the KEP Model. First design decisions are justified in Section 3.1. Then the mathematical description of the KEP Model is provided in parallel with its implementation, the KEPTool, in Section 3.2. Also, this chapter gives a summary and relations to other chapters in Section 3.3. Chapter 4 is then concerned with the setting for the evaluation of the KEP Model and the KEPTool. The procedure is outlined in Section 4.1. Section 4.2 presents the case and the data collection. The next two sections tell how the ratings for benefits, Section 4.3, and the ratings for efforts, Section 4.4, were gathered. Section 4.5 gives details about the preparation for the conducted interviews, and Section 4.6 describes the consecutive data analysis. The chapter is summarised in Section 4.7. Chapter 5 presents the results of the evaluation. Thereby, Section 5.1 shows the results for the evaluation of the proposal, which corresponds to sub-objective 1. Section 5.2 and Section 5.3
give the results for the factors and weights, corresponding to sub-objective 2 and 3, respectively. Then Section 5.4 presents the result for the rating procedure aiming at sub-objective 4. Section 5.5 gives the identified requirements for the user interface of the KEPTool corresponding to sub-objective 5. Next Section 5.6 shows potential future application scenarios of the KEPTool and their respective benefits, which is aligned with the final sub-objective 6. The final Section 5.7 concludes the chapter. Chapter 6 reviews and concludes the thesis with respect to the seven guidelines for design science research after Hevner et al. (2004).

A disclaimer at the end: The real-world application and evaluation of the KEP Model was conducted within the LL project. The LL project is supported by the European Commission through the 7th Framework Programme, Grant Agreement #318209, under the DG Information society and Media (E3), unit of Cultural Heritage and Technology-Enhanced Learning. The LL project started on 1st November 2012 and runs for 4 years. It is classified under the project type “Large-scale integration project” and is an answer to the project call ICT-2011.8.1-a, “Technology Enhanced Learning systems endowed with the capabilities of human tutors”. The KEP Model, its implementation the KEPTool, and the evaluation is part of the work package 3 (WP 3). WP 3 is headed by Creating and Maturing Instructional Material—Interacting with Digital Artefacts. Within the LL project, the KEP Model and KEPTool aim at the objective O3.2. The objectives are to “develop a conceptual model for collective development and improvement of boundary objects”, to “develop (possibly context-dependent) indicators for the maturity and relevance of boundary objects” and to “provide services and tools for creating awareness, establishing trust, triggering improvement, and supporting a gardener role in a community” (LL project proposal, 2012, p. 40). The related task, T3.2, is the “iterative co-design and development of methods and tools for selecting and remixing multimedia boundary object. This aims at technological support for selecting appropriate boundary objects and enhancing them in a low-barrier way. Within this task, tools/tool components and their underlying methodological concept is developed iteratively in a co-design process with target users”.
2 Foundations

This thesis starts with an introduction to the Knowledge Element Preparation Model (KEP Model) because the KEP Model is at the centre of this work. It forms the basis for the implementation of the KEPTool and both are the focus of the performed evaluation. Thus, Section 2.1 gives an informal introduction to the KEP Model. Then, Section 2.2 places the KEP Model in the context of design science research and discusses implications. The KEP Model can be seen as (part of) a decision support system, thus Section 2.3 is concerned with an introduction of those. Based on the consideration of these two sections, the next Section 2.4 discusses the evaluation of DSSs. The chapter is summarised in the last Section 2.5.

2.1 Introduction to the KEP Model

The KEP Model has been developed to support a decision maker to find knowledge elements, which are best suitable for preparation according to adaptation criteria (Thalmann, 2012). To give an example: a knowledge element might be a video promoting straw construction\footnote{For example www.youtube.com/watch?v=iCn3V51KywQ}. An adaptation criterion could be “language”. The preparation according to this adaptation criterion would be to translate the video into another language to make it more accessible to its recipients. The KEP Model helps a decision maker to decide, which knowledge elements should be selected for preparation by weighing the benefits of such a preparation against its efforts. The outline of this decision making process is shown in Figure 2.1, which is simplified from Thalmann (2012, p. 274).

First, one has to structure the domain, e.g., classify knowledge elements. Then, in parallel one has to, as indicated by the $\land$ operator, determine the need and the effort for preparations. In the next step, those are contrasted against each other. Finally, a decision on which preparations are to be performed has to be taken.

The following definition of knowledge element is taken from Thalmann (2012, p. 39): “A knowledge element is an electronically accessible and reusable exter-
nalised piece of knowledge, which is not restricted to a certain media format and which can be combined with other knowledge elements.” The key point of this definition in the context of this thesis is the reusability of knowledge elements. This enables and justifies their preparation according to adaptation criteria. The following definition is again taken from Thalmann (2012, p. 59): “[Adaptation criteria] represent aspects to which contents can be prepared, to which versions of prepared contents can be stored and to which contents can be delivered adaptively”. Further, adaptation criteria “describe the characteristics of an adaptation need on a conceptual level” (Thalmann, 2014, p. 46). Thalmann (2012, pp. 58) established 13 adaptation criteria with a structured content analysis. He then validated them with two expert surveys. First, he received feedback from developers of adaptive systems considered in the structured content analysis. In the second step, he consulted authors of papers that describe adaptive systems or systems dealing with adaptivity. Thereby, he identified 13 adaptation criteria: bandwidth, content preferences, device requirements, didactical approach, knowledge structure, language, location, preferences for media type, presentation preferences, previous knowledge, user history, user request, and user status (Thalmann, 2014, pp. 54). A preparation task is the preparation of a knowledge element with respect to an adaptation criterion. Such a preparation task can be performed either manually or automatically.

After establishing the basic definitions, knowledge element, adaptation criterion, and preparation task, Figure 2.2 gives a schematic overview over the KEP Model. As can be seen on the left side of the figure, the model works on three input data sets. The knowledge elements and the adaptation criteria are described above. The resources constrain the means available to prepare knowledge elements according to adaptation criteria. The KEP Model currently considers the capacity of employees.

The factors in the second block of Figure 2.2 are rated by (human) deciders. This rating forms the basis of the decision procedure. To reduce the rating effort, the KEP Model assumes that each knowledge element is assigned to exactly one
topic and exactly one type. Then, instead of each individual knowledge element, topics and types are rated and the ratings for topics and types are transferred to the individual knowledge elements. Knowledge elements, their topics and types, adaptation criteria and the resources for preparation tasks are rated with respect to, in total, 19 factors: (1–2) the importance of topics and types, (3) the need for preparation tasks according to adaptation criteria, (4–5) the complexity of topics and types, (6–11) the experience and minimal required experience of employees with topics, types and adaptation criteria, (12) the tool support, (13) the expected quality, (14) the feasible level of quality, (15–16) the potential of reuse of preparation tasks for topics and types, (17) the size of knowledge elements, (18) the feasibility of preparation tasks, and, (19) the capacity of the employees. As can be seen in the third block in Figure 2.2, the model also gives the decision maker the possibility to weight the factors. That is, he or she can determine the influence a factor has within the KEP Model. The last block in Figure 2.2 shows the expected output: a selection of knowledge elements, which are best suitable for preparation. This selection is based on the provided ratings of the factors and their influence on each other dictated by the weights.

The remainder of this section is devoted to the definition of the above factors. As mentioned before, the KEP Model weighs the benefits of the preparation of a knowledge element against the effort. The benefit of a preparation depends on the first two factors: importance and need. The importance of topic and type indicates the benefit, a preparation of a knowledge element with this topic and type would bring to the organisation. It focuses on the selection of knowledge elements which are targeted by the preparation efforts. The rating for the importance is highly organisation specific (Thalmann, 2012, p. 174). Conversely, the need for an adaptation
criterion focuses on the need for a preparation task with respect to an adaptation criterion (Thalmann, 2012, p. 181). The need for a preparation task according to an adaptation criterion is independent of how the preparation task is performed, i.e., manually or automatically.

These benefits are contrasted with the effort required for a preparation. The effort and difficulty of a preparation task generally increases with the complexity of a knowledge element (Thalmann, 2012, p. 223). Complexity is rated with respect to adaptation criteria, which dictate the preparation task. The experience of an employee influences the effort required for preparing a knowledge element (Thalmann, 2012, p. 225). The tool support depends on a knowledge element’s type and estimates the range of supporting tools, not limited to information and communication technology, for the preparation of a knowledge element (Thalmann, 2012, p. 228). The expected quality of the content influences the effort required to prepare an knowledge element (Thalmann, 2012, p. 229). In general, the possibility for better quality rises with increasing effort. The reverse, that more effort increases the quality, might not hold. The maximal feasible level of quality binds the effort invested in preparing a knowledge element (Thalmann, 2012, p. 238). The potential for reuse expresses the opportunity to save effort needed to prepare knowledge elements (Thalmann, 2012, p. 230). The size of a knowledge element influences the effort needed for preparation (Thalmann, 2012, p. 222). The feasibility of a preparation according to an adaptation criterion ensures, that the preparation of a knowledge element is practical and, indeed, feasible (Thalmann, 2012, p. 236). The capacity of an employee ensures that an employee is not overloaded and can prepare the assigned knowledge elements. It is measured with respect to the required effort for a given time (Thalmann, 2012, p. 279).

This section gave an introduction to the ideas and concepts behind the KEP Model. A mathematical description of the KEP Model is the basis for its implementation and can be found in Section 3.2.

2.2 Design Science Research

In this section Design Science (DS) research is introduced and related to the KEP Model. Then seven guidelines of DS research as established by Hevner et al. (2004) are presented. Next, the cycle model of DS research is considered. Lastly, the DS research methodology process model after Peffers et al. (2007) is investigated.

DS research aims at creating new and innovative artefacts (Hevner et al., 2004,
These artefacts are to be presented in a structured form and may range from software, formal logic and mathematics to informal descriptions (Hevner et al., 2004, p. 77). Hevner et al. (2004, p. 82) include constructs, models, methods, and instantiations in their definition of a DS artefact, but explicitly exclude people, elements of an organisation, and evolution over time. Following this definition, the KEP Model can be considered an artefact—a model described concisely in mathematical notation (see Section 3.2 for a precise description). Hevner et al. (2004) developed seven guidelines for DS research to provide a “conceptual framework and clear guidelines for understanding, executing, and evaluating research” (p. 75). These guidelines shall be presented here. Guideline 1 states that DS research “must produce a viable artefact”, which addresses an important problem and the description must enable an implementation (Hevner et al., 2004, pp. 82). Guideline 2 focuses on the relevance of the problem, i.e., DS has to “develop technology-based solutions to important and relevant business problems” (Hevner et al., 2004, pp. 84).

Guideline 3 is concerned with the evaluation and thus very important to this thesis and will be presented in more detail. As pointed out by, Hevner et al. (2004, p. 85) the “utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods”. Through an evaluation both the artefact and the design process can be improved by the feedback information and the better understanding of the problem (Hevner et al., 2004, p. 78). For Hevner et al. (2004, p. 85) the evaluation includes the technical infrastructure, in which the artefact is integrated, the organisational environment. The artefact can be evaluated with respect to “functionality, completeness, consistency, accuracy, performance, reliability, usability, fit with the organisation, and other relevant quality attributes” (Hevner et al., 2004, p. 85). Hevner et al. (2004, p. 86) summarise typical methods for evaluating an artefact and their results can be found in Table 2.1. The chosen evaluation method must fit with the designed artefact and the measures chosen for evaluation (Hevner et al., 2004, p. 86). As established by their literature review, Arnott and Pervan (2012, p. 938), found that most evaluation methods for DSSs are simulation, scenarios, and case studies, as well as a experiments. They encourage the inclusion of qualitative methods such as focus groups. Artefacts with a mathematical foundation, such as the KEP Model, allow for quantitative evaluations, like optimisation proofs, analytical simulations, or quantitative comparisons, where the placement of the artefact in an (organisational) context allows for empirical and qualitative methods (Hevner et al., 2004, p. 77). Surprisingly, Arnott and Pervan (2012, p. 935) also conclude, that evaluation is the “biggest weakness in DSS design
Observational
- Case study: study artefact in depth in business environment
- Field study: monitor use of artefact in multiple projects

Analytical
- Static analysis: examine the structure of artefact for static qualities
- Architecture analysis: study fit of artefact into technical information system architecture
- Optimisation: demonstrate inherent optimal properties of artefact or provide optimality bounds on artefact behaviour
- Dynamic analysis: study artefact in use for dynamic qualities

Experimental
- Controlled experiment: study artefact in controlled environment for qualities

Testing
- Functional (black box) testing: execute artefact interfaces to discover failures and identify defects
- Structural (white box) testing: perform coverage testing of some metric in the artefact implementation

Descriptive
- Informed argument: use information from the knowledge base to build convincing argument for the artefacts’s usability
- Scenarios: construct detailed scenarios around the artefact to demonstrate its utility

Table 2.1: Design evaluation methods after Hevner et al. (2004, p. 86).

science research”. They find that overall more than 40 % of DSS DS projects do not undertake any formal evaluation, and proclaim, that some evaluation should be mandatory.

Guideline 4 is concerned with research contributions. DS research must provide a “clear and verifiable contribution” (Hevner et al., 2004, p. 87). This contribution may be an design artefact, foundations, or new and innovative methodologies. They emphasise the importance of an artefact to be implementable. The next Guideline 5 is concerned with research rigour and demands that “rigorous methods in construction and evaluation of artefacts” have to be employed (Hevner et al., 2004, p. 83). Guideline 6 investigates the iterative procedure of DS, and sees DS as a search process to discover an effective solution to a problem (Hevner et al., 2004, p. 88). The final Guideline 7 states the importance of the communication of the research to a technology oriented, as well as to a management oriented audience (Hevner et al., 2004, p. 90).
When introducing the guidelines, Hevner et al. (2004, p. 82) advise against a “mandatory or rote use of the guidelines”. They argue that the guidelines should be adapted to the specific research project, but suggest that each guideline should be addressed. Contrary to this, Arnott and Pervan (2012, p. 940) believe that Guideline 1, 2, 3 and 5 should be mandatory. In this thesis, the guidelines shall be revisited to guide the conclusion in Chapter 6.

Figure 2.3 shows the three cycle view of DS research after Hevner (2007, p. 88). The central, tighter cycle, the Design Cycle iterates between the construction of an artefact and processes, and its evaluation (Hevner, 2007, p. 90). For the KEP Model a model demonstration has been performed by Thalmann (2012, p. 281), and it is in for another round in this thesis. The input for further development is given by the requirements from the Relevance Cycle, and evaluation theories and methods from the Rigour Cycle (Hevner, 2007, pp. 90). Therefore, in this thesis, the relevance cycle, will provide further requirements from the introduction of the KEP Model to the environment (Hevner, 2007, p. 89). For the rigour cycle the input comes from this chapter.

Peffers et al. (2007) developed a DS research research methodology model, which is shown in Figure 2.4. The first activity, define problem & motivate, define the research problem and provide justification for the value of a solution (Peffers et al., 2007, p. 57). As the identification of the problem does not necessarily translate to objectives, the next activity, define objectives of a solution, investigates these objectives (Peffers et al., 2007, p. 57). The activity design & development is then

![Figure 2.3: Design science research cycles after Hevner (2007, p. 88).](image-url)
concerned with the creation of the artefact (Peffers et al., 2007, p. 58). Then, in the activity \textit{demonstration} the artefact demonstrates is use by solving an instance of the problem (Peffers et al., 2007, p. 58). The \textit{evaluation} shows how well the artefact supports the solution to the problem (Peffers et al., 2007, p. 58). Finally, the last activity, \textit{communication} communicates the efforts to researches and relevant audiences such as practising professionals, if appropriate (Peffers et al., 2007, p. 59). It is not expected, that the research always proceeds in sequential order, in fact, several possible research entry points are given, each corresponding to an activity: \textit{problem centred iteration}, \textit{objective centred solution}, \textit{design & development centred iteration}, and \textit{client/context initiated}.

The problem was defined and motivated and its objectives have been defined in Thalmann (2012, pp. 159), and the \textbf{KEP Model} has been developed as an artefact. Building on this previous knowledge, the next activity, the \textit{demonstration}, i.e., the application of the \textbf{KEP Model}, is the starting activity for this thesis. The research entry point for this work is \textit{client/context initiated}, which enables a consecutive \textit{evaluation}. The output of this evaluation is expected to show further requirements for the design and development of the \textbf{KEP Model}.

This section motivated the next steps in the development of the \textbf{KEP Model} as a DS artefact. It highlighted the necessity of iterative evolution and evaluation. Therefore in the next section, the \textbf{KEP Model} as a DSS is discussed, and based on this investigation specifics for the evaluation of DSSs are given in Section 2.4.
2.3 Decision Support Systems

The KEP Model supports a decision maker in selecting knowledge elements best suitable for preparation. Thus, it can be classified as a decision support system (DSS). This calls for some closer inspection of DSSs in this section.

First, some definitions will be given and investigated with respect to the KEP Model. Historically, the name decision support systems was coined by Gorry and Morton Scott (1971). The authors introduced DSSs by distinguishing them from management information systems. They defined DSSs to deal with semi-structured and unstructured problems, as opposed to structured and less critical problems, where automation is feasible (Hosack et al., 2012, p. 317). The decision problem of the KEP Model, the selection of knowledge elements for preparation, is (unfortunately) not a well structured task, where automation is possible. The definition of Adelman (1992, p. 4) introduces two further aspects of DSSs. He defines DSSs as “interactive computer programs”, which “help decision makers [to] formulate alternatives, analyze impacts, and interpret and select appropriate options for implementation”. Adelman (1992) sees DSSs as computer programs and he highlights the interaction with and support for the user. These two aspects have been picked up by several authors. Arnott (2008, p. 127) defines DSSs as “computer-based information systems”, which serve the purpose to “improv[e] the process and outcome of decision making”. Arnott (2008) also sees computers as basis for DSSs. Contrary to Adelman (1992), they do not emphasise the support to the user but the impact on the decision making outcome and process. Similarly, Arnott and Pervan (2008, p. 657) state that “[e]ssentially, DSS is about developing and deploying [Information Technology (IT)]-based systems to support decision processes”. This definition gives an even stronger focus to IT and computers. This notion is also supported by Turban et al. (2011, p. 16), they argue the term decision support system may be seen as a conceptual methodology to describe any computerised system, that supports making decisions in an organisation. Although this is a broad definition, i.e., any computerised system, the system still has to be computerised. This is also the case for Sauter (2010, p. 13), who understands a DSS as a “a computer-based system”, which “supports choice by assisting the decision maker in the organization of information and modeling of outcomes”.

Strikingly, most definitions pick up the aspect of computer programs as the basis for DSSs. Unfortunately computers do not work well with unstructured decision
problems. Alas, even some simple yes/no questions are undecidable for them\(^2\). Similarly, Hosack et al. (2012, p. 325) argue, that the focus of research for decision support has been on the technical side, rather than the behavioural. Thus, DSSs have been seen as a technological, rather than an organisational concept. But, DSSs are socio-technical systems and not simply technical ones (Finlay and Forghani, 1998, p. 57), as the success of a DSS relies on the involved people.

Thus, before further aspects of DSSs are introduced, the focus will be on the users, or decision makers. They are a crucial aspect when considering DSSs. Therefore, first an observation by Pick and Weatherholt (2013) is discussed. They argue, that DSSs can be distinguished from other computer-based systems by two aspects: (1) the focus on decision making, and (2) the interactive use. DSSs are interactive in the sense, that they require the system and a user, a decision maker, to contribute to the decision process (Pick and Weatherholt, 2013, p. 7). This distinction also recognises, similarly to Adelman (1992), the interaction between the system and the users. Or, as observed by Forgionne (1999, p. 95), the promise of DSSs to improve the quality of decisions base on the “coupling [of] the intellectual resources of users with the capabilities of the computer”. Albeit, the earlier definition of DSS by Turban et al. (2011, p. 16) does not explicitly mention the user’s role in a DSSs, they state that although the user is “not listed as a major component of DSS, by definition provides the human intellect” (Turban et al., 2011, p. 107). They recognise that the users provide the expertise in the use of a DSS. Turban et al. (2011, p. 107) even suggest that after the replacement of a user by a less knowledgeable user, the DSS will generally be less effective. Hosack et al. (2012, p. 316) argue, that the use of DSS “enable the users to understand a large number of parameters and relationships”, which shifts the focus back to the support a DSS is supposed to provide. Similarly, for Phillips-Wren et al. (2004, p. 324), a DSS “assists the decision maker with a particular decision problem”.

The focus on the user is also vital for this thesis. Albeit it also features a computer program, i.e., the implementation of the KEP Model the KEPTool (cf. Chapter 3), the KEPTool, and computers in general, are seen as a tool and not the central aspect of DSSs. In this thesis the user is the central part of the DSS, which will become evident, when considering the users role in the development of a DSS.

A DSS has to evolve. This evolution is triggered by the users’ experience with the system and the specification of their needs (Kim and Guimaraes, 1992, p. 29). In this evolution, the development of a DSS is cyclic and involves significant user par-

\(^2\)For example: Given two arbitrary computer programs. Do they always compute the same results?
As introduced in the previous section, cyclic evolution is also central for DS research, as can be seen in the DS research cycles (Figure 2.3) and the DS research methodology process model (Figure 2.4). The involvement of users in the development shapes the DSS. Perspectives from different users show different perceptions to the decision problem and highlight the importance of different features (Sauter, 2010, p. 375). However, a balance between the influence of the designers and implementers of the system and the users has to be maintained. Too much influence of the users may lead to a lack of standardisation, whereby the developers may focus too much on the same (Sauter, 2010, p. 377). Following these recommendations, the involvement of users is central to the development of the KEP Model and the KEPTool (cf. Chapter 4).

With this early focus on the user, further discussion about DSSs follow. DSSs come in many different flavours and different classifications have been developed. Here, only aspects relevant to the KEP Model will be discussed. The interested reader is referred to an in-depth historical analysis of DSSs by Hosack et al. (2012).

Turban et al. (2011, p. 44) state that a DSS includes at least one model as a simplified representation and abstraction of reality. For *model-driven DSSs* the model is the dominant component in the architecture of the DSS (Power and Sharda, 2007, p. 1045). Model-driven DSSs have been named model-oriented, model-based, or quantitative in the literature (Power and Sharda, 2007, p. 1045), and use algebraic, decision analytic, financial, and optimisation models (Power and Sharda, 2007, p. 1044). Pick and Weatherholt (2013, p. 15), restrict model-driven DSSs to DSS which have as basis *mathematical* models; they state the “driving technology is one or more mathematical model(s)” Their given examples are systems which include simulation models or optimisation models in mathematical programming. Model-driven DSS support the user with analysing a situation by data and parameters given by the user (Power and Sharda, 2007, p. 1045). The user can manipulate the model’s parameters to observe the sensitivity of the output or perform a “what-if” analysis (Power and Sharda, 2007, pp. 1044). According to these definitions, the KEP Model can be classified as the central component in a model-driven DSS—as a mathematical as well as an optimisation model.

Model-driven DSSs focus on accessing and manipulating the model (Power, 2003, p. 24). So next the connecting link between the user and the system is discussed—the user interface. Through an easy-to-use user interface, the model in a model-driven DSS becomes accessible to non-technical specialists (Power and Sharda, 2007,
The interface has to facilitate the input of values by the user, to allow for the manipulation of values, and to present the results to the user (Power and Sharda, 2007, p. 1052). Zhu and Chen (2008, p. 716) even argue, that for the support of decision making more focus should go into the development and deployment of different visualisation systems rather than only the development of advanced technologies.

In another categorisation the KEP Model and the KEPTool can be classified as a personal decision system (PDSS). PDSS are usually small-scale systems, which are developed for independent users to support them with a decision task (Arnott and Pervan, 2008, p. 657). This category, however, focuses more on the use and context it is employed, i.e., small-scale and independent user. The KEP Model is not restricted to independent users, rather its implementation, the KEPTool currently does not explicitly support collaboration between multiple users.

The remainder of this section is devoted to the expected benefits and success factors of DSSs. First, the challenges attached to measurements are introduced. A first difficulty lies in the quantification of qualitative benefits. This quantification is highly subjective and subject to uncertainty, and, further the units of measurements may not be comparable across the system, the estimation is specific to the environment and may change (Kim and Guimaraes, 1992, p. 34). Some measures may be expressed in numbers, e.g., organisational performance or personal efficiency, but others are profoundly subjective, e.g., decision maker proficiency. Moreover, the measures may conflict, as e.g., the maturity of the decision maker may decrease the personal efficiency (Forgionne, 1999, p. 99). A further difficulty is a consequence of the application scenario for DSSs. As mentioned before, they are typically employed for unstructured or semi-structured decisions. Measuring the quality of such a decision is tricky. Decisions in such situations cannot be easily classified as “good” or “bad”, “right” or “wrong” (Rhee and Rao, 2008, p. 368). If one considers solely the outcome of a decision, e.g., profits, “good”, well informed decisions can lead to bad outcomes (Papamichail and French, 2005, p. 95), because of chances and other not yet understood factors (Sauter, 2010, p. 386). Therefore, as suggested by, e.g., Sauter (2010, p. 386), good and bad decisions must be separated from good or bad outcomes. Forgionne (1999, p. 99) suggests a relationship between the process of decision making and the outcome. He argues, that that enhanced outcomes result from improvements in the decision making process. He even suggests, that outcome enhancements, where it cannot be explained how the decision making process was improved, cannot be reliably credited to the use of the DSSs. So DSSs have an
impact on the outcome and the process of decision making (Phillips-Wren et al., 2004, p. 323), and given a successful implementation, the DSS can improve both, the output and the process of decision making (Forgionne, 1999, p. 97). Related to the notion of process and outcome of decision making is the notion of the efficiency and effectiveness of a DSS. Efficiency is usually related to the process, where effectiveness is related to the outcome (Hung et al., 2007, p. 2094). The measurements of success in a DSS are sometimes related to either outcome and process measurement, or, efficiency and effectiveness measurements (Hung et al., 2007, p. 2094).

Next, some measurements found in the literature will be presented. In a literature review, Hung et al. (2007, pp. 2094) identify four success measures for DSSs. They find, that many studies have chosen the user satisfaction and/or decision-making satisfaction, decision quality, and business profitability as success measures for DSSs. As discussed before, measuring improvements at the outcome of a DSS is difficult. Improvements in the decision making process may be easier to measure than the quality of the decision. Process improvements enhance the users’ ability of decision making (Forgionne, 1999, p. 98). So most process measurements are related to use and user. Possible measurements for the decision making process are, the alternatives considered (Pick and Weatherholt, 2013, p. 12), frequency or length of system usage, or the the decision speed (Hung et al., 2007, p. 2094). Also, the decision process is documented and this can raise the confidence in the decision (Pick and Weatherholt, 2013, p. 12). Other process related measures where suggested by Phillips-Wren et al. (2004): the proficiency of the decision maker, the proficiency of the steps of the decision maker, and changes to the organisation and the decision maker. Measures for the outcome proposed by the literature include the decision performance and user satisfaction (Hung et al., 2007, p. 2094). Phillips-Wren et al. (2004, p. 325) state that outcome improvements are indicated by organisational performance, e.g., increased sales or decreased costs, or, as suggested by (Forgionne, 1999, p. 97), the boosts of information flows. As some measures already hint, again the proper use and guidance is critical to the success of a DSS. Hence, the performance of a DSS depends on the user (Turban et al., 2011, p. 107). The observation of Sauter (2010, p. 372) shifts the ballast more to the implementers of a system. She observes, that the success of a system “depends to a large measure on the quality of the system and the ease and flexibility of its use”. She states, that the users will not use the system, if they do not perceive the system as facilitating their decision. Similarly, Finlay and Forghani (1998, p. 64) argue that the DSS has to provide a high quality and quantity of information, that it has a suitable learning infrastruc-
ture and must be easy to use. Further they argue, that the complexity of the model in a DSS has to match the user’s capabilities and conclude, as mentioned before, that the users “need to be involved in the DSS development”.

This section introduced different definitions of DSSs and drew the attention to a central part in the DSS: the user. Then the KEP Model was classified as the basis for a model-driven DSS, the KEPTool. The section ends with an investigation of the benefits expected of a DSS. Unfortunately, the expected benefits of a DSS are often not realised (Finlay and Forghani, 1998, p. 53). As pointed out by Hosack et al. (2012, pp. 321) in their historical perspective on DSSs, the use of DSSs does not always lead to success. The authors identify as causes for failures: poor design or poor implementation, lack of use, understanding and education, poor managerial decision making, and, that no restrictions have been placed on the automated usage of DSSs in critical situations. So, the next section will be concerned with the detection and avoidance of such failures: the evaluation of DSSs. The next section is prefaced with a word of warning by Kim and Guimaraes (1992, p. 29): “DSS evaluation is difficult because of their dynamic nature”.

2.4 Evaluation of Decision Support Systems

As motivated in Section 2.2 and Section 2.3 evaluation is crucial for a DS artefact and a DSS. This section provides foundations for the evaluation of the KEP Model, which can be seen as a DS artefact and a DSS. First, some definitions for evaluation, and in particular, formative evaluation, are discussed. Then, the three-faceted approach and methods for evaluating DSSs are presented.

Patton (2002, p. 10) defines evaluation as the “systematic collection of information about the activities, characteristics, and outcomes of programmes to make judgements about the programme, improve the programmes effectiveness, and/or inform decisions about future programming”. This definition is not specific to DSSs, but rather to the evaluation of any programme. But it is very broad and includes several aspects relevant for any evaluation, namely, the collection of information, which will be a major aspect in the application of the KEPTool as can be seen in Chapter 4. Moreover, the definition gives the purpose of evaluation, namely the enabling of judgements. Especially, the judgements about the future programming are of interest in the context of this thesis. A common distinction in evaluation is the distinction between summative and formative evaluation which is credited to Scriven (1967, p. 5). This thesis is concerned with formative evaluation. The un-
derlying assumption for formative evaluation is the the continuation of the system, whereby the objective is to find improvements for the system (Pick and Weatherholt, 2013, p. 8). Usually, the system is iteratively, formatively evaluated throughout the development process to eliminate weak points and to reach the desired objectives (Rhee and Rao, 2008, p. 319), to find out problems and to find areas for improvement (Leroy, 2011, p. 205). As pointed out by Leroy (2011, pp. 204), formative evaluation is also called constructive evaluation and is performed to provide helpful direction for future development. She also suggests, that formative evaluation is particularly suitable for testing individual components, as which the KEP Model can be seen. Formative evaluation fits very well with an iterative software development process (Leroy, 2011, pp. 205). The concept of formative evaluation fits well with the cycle model and the DS research methodology process model in DS, which requires input for requirements from the environment and iteratively improves the artefact. Also, as already explained in the previous section, DSSs have to evolve, i.e., they have to be replanned, modified, expanded, and improved. The evaluation of a DSS is crucial for the evolution of a DSS to progress in the desired direction (Kim and Guimaraes, 1992, p. 29).

Formative evaluation methods give feedback in requirement-driven development process to improve the system (Adelman, 1992, p. xi). It is important, that users different from the developers and designers give this feedback, as the former are too close to the system, whereby the latter will have different own mental models and expectations of the system (Leroy, 2011, pp. 204). Further, a formative evaluation early on in the system development allows for changes timely in the development cycle, where they are relatively easy and inexpensive (Adelman, 1992, p. 5). Following these observations, and motivated by DS research principles, a formative evaluation of the KEP Model and KEPTool in an early phase including perspectives from users is vital for the development and is the research objective for this thesis—the evaluation of the KEP Model and the KEPTool.

Most works on evaluation of DSSs rely on the multi-faceted evaluation approach developed by Adelman (1992). He distinguishes tree facets for evaluation: technical, empirical, and subjective (Adelman, 1992, pp. 15). These three facets will be discussed in the following.

The technical facet inspects the system from an internal perspective, i.e., algorithmic or heuristic, and an external perspective, i.e., systemic input/output (Adelman, 1992, p. 16). Adelman (1992, p. 15) described the technical facet succinctly as “looking in the black box”. The system’s logic, algorithm, and data flow are assessed by
this facet (Rhee and Rao, 2008, p. 315). Technical aspects are measured by tests, the validation of its components, and the examination of the knowledge sources (Papamichail and French, 2005, p. 94). For example, it is checked whether database calls retrieve the correct information, or the models are manipulated to observe whether the manipulation is performed correctly (Sauter, 2010, p. 382). Technical evaluation can serve to eliminate coding errors, check whether the system is well built and produces sound and accurate output (Papamichail and French, 2005, p. 85). Parts of the DSSs can be tested in isolation, but unfortunately, since the developers will not know the whole range of uses the users will subject the DSS to, not all possibilities can be tested (Pick and Weatherholt, 2013, p. 9). The technical facet is very important, because if the technical requirements on the system are not met, the system will not be used, rendering it a failure (Sauter, 2010, p. 382).

For the empirical facet, objective measures to test the system’s performance are obtained and assessed (Adelman, 1992, p. 16). This serves the verification of the system’s effectiveness. This facet has the focus on performance with the support of DSSs (Rhee and Rao, 2008, p. 315). So, the empirical facet includes tests for measuring the performance of the DSS with its users, e.g., whether the decisions are reached faster or more information is used (Papamichail and French, 2005, p. 94). As pointed out by Rhee and Rao (2008, p. 315) empirical evaluation serves to verify the effectiveness of the DSS on the one side, but it also shows direction towards the improvement of the system. A method for empirical evaluation is panel-based evaluation. The aim of panel-based evaluation is to show that a DSS leads to decisions at least as good as decisions without the system. Therefore the output of a DSS is compared against the recommendation by one or several experts (Papamichail and French, 2005, p. 94). A similar method is the Turing test. Here the output of a DSS and the recommendation of experts are provided to a third party assessor. The assumption is, that if the assessor can not distinguish between the systems’s and the expert’s recommendation, the DSS can be judged as working properly (Sauter, 2010, p. 385). Differently to panel-based evaluations, the Turing test always requires third party assessors (Papamichail and French, 2005, pp. 94). This is not necessarily required for panel-based evaluations, and when the same experts are employed, which leads to the danger of systematically under- or overestimating their own or the system’s performance (Papamichail and French, 2005, p. 94). A critique to both approaches is the assumption, that the DSS should match an expert’s performance. With this assumption, one has to take into account, that emulating human experts can lead to the same mistakes they make (Papamichail and French, 2005, p. 94).
A further problem with those approaches is that if the settings in the DSS change, e.g., some further rules or data is added, the system has to be re-assessed by the experts (Papamichail and French, 2005, p. 94). Another possibility to assess the performance of a DSS is to assess the quality of decisions taken by users with the help of the system (Papamichail and French, 2005, p. 95). As mentioned before, DSS are usually deployed to solve unstructured or semi-structured problems (Pick and Weatherholt, 2013, p. 7) and “good” decisions do not necessarily result in “good” consequences (Borenstein, 1998, p. 228). An assessment of the decisions taken by the system is difficult and such assessments lie with the experts’ preference (Rhee and Rao, 2008, p. 313). The performance of a DSS can also be determined by comparing it against other DSSs (Papamichail and French, 2005, p. 95). For example, it can be tested against other existing systems or different versions of the system (Leroy, 2011, pp. 205).

For the subjective facet the system is evaluated from the user’s, or potential user’s, perspective (Adelman, 1992, p. 16). The subjective evaluation investigates the effect on the interrelationship among the DSS, the users, the organisation, and environment (Rhee and Rao, 2008, p. 316). The subjective facet is concerned with the collection of opinions to measure the utility of the DSS and to find out whether the user’s needs are addressed (Papamichail and French, 2005, p. 85). The aim is to establish whether the system addresses an important problem, whether the problem-solving approach is systematic and logical (Papamichail and French, 2005, p. 94). A typical example for the subjective facet, investigating the relationship between the DSS and its user, is the evaluation of the user interface with respect to ease of use, understandability, and clarity (Rhee and Rao, 2008, p. 316). Users can directly assess their own or the system’s performance (Papamichail and French, 2005, p. 96). Care must be taken, when performing subjective evaluations, especially when the development of a system is driven by users. If the system is solely designed to meet the requests of the potential user’s, it will perform well in subjective evaluations. Unfortunately, this does not imply, that the developed system is sound and good (Rhee and Rao, 2008, p. 314).

To summarise, the multi-faceted approach highlights three facets to which DSSs may be evaluated: the technical, empirical, and subjective facet. In this thesis, the focus is on the subjective facet.

Some authors suggest more hard-set methods for the evaluation of a DSS. One well known method is the cost/benefit analysis. Similar to the KEP Model, it compares the benefits of a DSS against its costs. The cost/benefit analysis produces a
dollar figure and is thus easiest for management (Kim and Guimaraes, 1992, p. 32). Unfortunately, as discussed in Section 2.3, the benefits of a DSS are difficult to quantify. Moreover, the method’s limitation to economic goals, does not provide any insight on the further evolution of a DSS (Kim and Guimaraes, 1992, p. 34). The evaluation of the costs and benefits might be useful to an organisation, but it does not show directions to make the DSS better (Sauter, 2010, p. 387). A similar method is the value analysis, where the focus is on the perceived value and the benefits, whereby the costs should stay within an acceptable range, i.e., a threshold is defined for the required benefits (Kim and Guimaraes, 1992, p. 32). Similarly, the multi-attribute utility value approach combines individual values to an overall value by weighing them to arrive at a single value (Kim and Guimaraes, 1992, p. 32).

Also Pick and Weatherholt (2013, p. 8) identify different types of evaluation: The cost-effectiveness, which measures the outcomes in non-financial terms or measuring the overall effectiveness of a system, assess how effective the system is in assisting to reach companies goals. A DSS may also be put through an efficiency evaluation, where one determines if the system enables more output with no increase in inputs, or less input with current level of output (Pick and Weatherholt, 2013, p. 8). As mentioned in Section 2.3, DSSs have an impact on the output and the process of decision making. Therefore, a requirement on the evaluation could be that it incorporates both aspects (Forgionne, 1999, p. 105). Phillips-Wren et al. (2004) developed a multi-criteria framework for the evaluation of DSS. Their framework is based on the Analytical Hierarchy Process (AHP), developed by Saaty (1977), and includes outcome and and process-oriented aspects of DSSs simultaneously. The AHP structures a complex problem with multiple criteria (Kim and Guimaraes, 1992, pp. 32). To employ such a multi-criteria evaluation, the criteria are structured in a hierarchy and allocated weights which reflect their respective importance from which an overall score for the system is computed (Papamichail and French, 2005, p. 96).

The end of this section is concerned with the rift between a scholar’s and a management’s interest in the evaluation of DSSs. As became clear in this section, different approaches for the evaluation of DSSs are suggested by the literature. Rhee and Rao (2008, p. 313) identify a gap between the interest about the evaluation of a DSS from a scholar’s and a practitioner’s perspective. Whereas the scholar’s goal is to gain insight for later use, the ultimate goal for practitioners is to improve the DSS and the performance of the decision-making process. Academics evaluate their developed DSSs to document quality of their scholarly contribution for publication purposes (Pick and Weatherholt, 2013, p. 9). Particular for DSS, Arnott and Per-
van (2008, p. 661) state “relative lack of exposure of academics to contemporary professional practice” is problematic, and they conjecture, that the concentration on natural science research to get acceptance is evident in DSS research. In particular in DS research researchers need to demonstrate the utility and quality of a design artefact. Therefore, a crucial aspect of research is evaluation (Hevner et al., 2004, p. 85). But, researchers need to select problems considering the professional relevance and interest (Arnott and Pervan, 2008, p. 667). Highly abstract representations are blamed with having no relationship to the real world (Hevner et al., 2004, p. 99). This section ends with a suggestion by Arnott and Pervan (2008, p. 667): “Researchers need to select problems with a consideration for professional relevance and interest, in addition to considering the recommendations of previous academic research.”

This thesis aims at both the academic’s and practitioner’s perspective. Therefore, the KEP Model is to be implemented and evaluated in a real world context, which is the research objective of this thesis.

2.5 Summary

The KEP Model, developed by Thalmann (2012) supports a decision maker to select knowledge elements best suitable for preparation with respect to adaptation criteria. Each knowledge element therefore has an assigned topic and type. The decision maker then rates 19 factors: (1–2) the importance of topics and types, (3) the need for preparation tasks according to adaptation criteria, (4–5) the complexity of topics and types, (6–11) the experience and minimal required experience of employees with topics, types and adaptation criteria, (12) the tool support, (13) the expected quality, (14) the feasible level of quality, (15–16) the potential of reuse, (17) the size of knowledge elements, (18) the feasibility of preparation tasks, and, (19) the capacity of the employees. Based on these ratings, and weights determining the influence of the factors, the KEP Model then computes the answer to the following question: Which knowledge elements should be prepared by which employees according to which adaptation criteria?

This informal introduction motivates and explains the general idea behind the KEP Model, which is central to this thesis. In particular, it provides the background information and reasons for the mathematical description of the KEP Model, which is given in Section 3.2 and is the basis for the implementation of the KEPTool.

The KEP Model can be considered a DS artefact. Different concepts of DS have
been presented: the seven guidelines by Hevner et al. (2004), the cycle model, and the DS methodology process by Peffers et al. (2007). Each of these approaches emphasises the iterative improvement and evaluation as central parts of DS. The cycle model and the DS research methodology served to clarify the requirements and the next steps for the further development of the KEP Model. The implementation of the KEP Model, given in the next Chapter 3, and the consecutive application and evaluation in an organisational environment in Chapter 4. The conclusion of this thesis, Chapter 6 will be guided by the seven guidelines for DS research.

The KEP Model is provides the basis for a DSS. In this thesis, DSS are seen as socio-technical system and the user plays a central role in the evaluation of the KEP Model, and the KEPTool, in Chapter 4. Thereby, the users provide the feedback to trigger evolution. Formative evaluation fits well with user driven evolution and the iterative development of DS artefacts.

The evaluation of a DSS is often divided in the three faceted approach by Adelman (1992): the technical, empirical, and subjective facet. The technical facet is concerned with technical aspects of the DSS, which is not the focus of this thesis and is thus left for future work. The empirical facet measures the performance of a DSS. This facet is neither the focus of this thesis, as it would require the introduction of the KEP Model in an organisational setting, which is beyond the resources of a thesis. Still the ideas of evaluating the proposal computed by a DSS by experts is taken up. Thus, the main motivation for this thesis is the subjective facet, which evaluates the system from a user’s perspective. The user evaluation is described in detail in Chapter 4. Some further evaluation methods, such as the cost-benefit analysis, value analysis, or the Analytic Hierarchy Process, are briefly investigated. These approaches are mainly motivated by business needs and settings, which are also out of scope for this thesis.
3 Implementation

The KEP Model, as informally described in Section 2.1, has been implemented. The implementation is called the KEPTool. Figure 3.1 shows the logo of the KEPTool. This chapter describes the implementation, which serves as a basis for the consecutive application in the case and the evaluation in Chapter 4. Therefore, in Section 3.1 the requirements and design decisions for the implementation are presented. Based on this considerations an adequate solver and a modelling language are chosen. The implementation is then described in Section 3.2. To this end a precise mathematical description of the KEP Model is paramount, which is also provided. Section 3.3 summarises the chapter.

3.1 Design Decisions

This section starts with requirements on the implementation of a DSS. Further, the benefits of a prototypical implementation are reviewed. Then, the selection of a suitable solver and modelling language is presented.

The implementation of a DSS is the realisation of a planned system. It involves the transformation of design to code, but also includes instantiation of databases, deployment, integration, and field testing, as well as the training of users and, important for this thesis, the evaluation (Sauter, 2010, p. 369). The whole process is beyond the scope of this work. Here, the focus is on a prototypical implementation and an initial evaluation by the potential users. An initial prototype implementation of the KEP Model has been done by Thalmann (2012, pp. 281), which focused on the model demonstration to highlight interdependencies between factors and weights. In course of this thesis, a further prototype is developed with the focus on an evaluation

Figure 3.1: Logo of the KEPTool.
The prototypical implementations fits well with the evolution of DSSs as described in Section 2.3. In a prototype, a small and important part of the system is realised, and on that basis the users can explain their needs for future developments (Sauter, 2010, p. 373). It enables the users to discuss specific issues, e.g., adequacy of the information, and reduces the likelihood of misunderstandings (Sauter, 2010, p. 372). Prototypes allow incremental changes to the system to enhance the fit to the user’s needs (Finlay and Forghani, 1998, p. 57). From a DS perspective, the “use of a prototype instantiation to demonstrate the efficacy of a design can provide strong evidence when used to show that a design works as intended, is useful for its intended purpose” (Peffers et al., 2012, p. 406). It supports the cyclic, feed-back driven development of DS research as presented in Section 2.2. But, Sauter (2010, p. 375) warns: “Too often, designers lose perspective on users’ needs and try instead to provide users with the latest ‘new technology’ or all of the ‘bells and whistles’ associated with the available technology”. This warning shall be kept in mind for the following: the selection of an appropriate solver.

The KEP Model poses a linear 0/1 optimisation (combinatorial) problem. This problem is NP-complete (Karp, 1972, p. 85) and a naive implementation is not feasible as the worst case time requirement grows exponentially with the size of the input. To solve such a problem a general-purpose algorithm, a solver, can be applied. A solver has the advantage to be reusable in different applications and providing high performance (Bordeaux et al., 2006, p. 1). But, no solver is superior in general (Zhou et al., 2012, p. 47). Further, Zhou et al. (2012, p. 47) state that it “requires extensive experimentation to find a right model and a right solver”.

Different paradigms for combinatorial search and optimisation problems exist, e.g., Constraint Programming, Integer Programming, or SAT solving (Zhou et al., 2012, p. 41). A further developing paradigm, briefly investigated for this thesis, is Answer Set Programming (Brewka et al., 2011). The decision between paradigms for a particular problem is a difficult task (Gebruers et al., 2004, p. 381). But, the selection of the ‘best’ paradigm was not the focus of this thesis. For practical purposes, the most straightforward paradigm was chosen: The KEP Model is a linear model, thus, it can be solved by a linear programming (LP) solver.

For the selection of a suitable LP solver, three knock-out criteria based on practical limitations were chosen. (1) The software has to be freely available. This is to counteract the problem encountered by González (2009), where the developed tool is free or free-ware, but relies on a commercial solver. Thus, the user is obliged to
obtain a license. However, as suggested by Meindl and Templ (2012), the use of a free solver may result in a decrease of performance. In their case study commercial linear programming solvers outperform free and open source solvers. (2) The solver has to be available for different platforms. At least the operating system Microsoft Windows has to be supported, as this is the developing platform. (3) The solver has to be actively developed.

Selection criteria for a solver can also be the ability to encode constraints easily, the readability and the performance (Jordan and Drexl, 1995, p. 160). Thus, to further narrow the knock-out criteria described above, rating criteria were taken into account. (1) The interfaces provided by the solver. (2) The performance of the solver in competitions and benchmarks, and (3) the ease of use and personal interest of the author.

Several LP solvers were reviewed with respect to these criteria. A good starting point is the website maintained by Mittelmann\(^1\), which provides a continuously updated benchmark test on the run time comparison of different commercial and free LP solvers. Next, three solvers, which have been investigated in detail are briefly presented.

The groove solver\(^2\) has a ‘free’, one year renewable, named-user academic license, supports different interfaces (C++, Java, .NET, Python, C, Matlab, R, Excel via Premium Solver Platform) and modelling languages (AIMMS, AMPL, GAMS, MPL). The license is, however, restricted to academic use.

The lp solver\(^3\), is published under the GNU Lesser General Public License (GNU LGPL) and can be called as library from C, VB, .NET, Delphi, Excel, Java. Further, there is a standalone solver available with input files in the MPS format and lp-format. It is available for Windows and can be called with, e.g., AMPL, MATLAB, O-Matrix, Scilab, Octave, or, R.

The GNU Linear Programming Kit\(^4\) (GLPK) is published under GNU General Public License (GNU GPL). It is available for the platforms UNIX, Linux, Windows and Mac OS X. The current version is 4.54 from March 2014 and written in ANSI C. It has a callable C library and a standalone solver (glpsol) which works with the GNU MathProg modelling language (GMPL). GMPL is a free subset of the modelling language AMPL\(^5\).

\(^1\)See plato.asu.edu/bench.html.
\(^2\)See www.gurobi.com/en.
\(^3\)See lpsolve.sourceforge.net/5.5.
\(^4\)See www.gnu.org/software/glpk
The preliminary investigation of the solvers showed, that the focus should not be on the solver itself, but rather on the modelling language. All the above solvers support the modelling language AMPL, or a subset thereof. Thus, the free subset, GMPL, was chosen to model the KEP Model. This allows a relatively easy integration with different solvers. For the solver, based on the above criteria, GNU GLPK was chosen. GLPK is free and easy to install (Pokutta, 2010). For this thesis, the standalone solver glpsol will serve. However, as mentioned before, because modelling language and solver are separated, the GLPK solver can easily be replaced by any solver accepting AMPL input.

Therefore, next some details about AMPL will be investigated, which also hold for its subset GMPL. The developers of AMPL, Fourer et al. (1990, p. 519), designed AMPL as a declarative language, that specifies a linear program by describing its components (Fourer et al., 1990, p. 553). The aim was to design a language, which resembles the algebraic notation used to describe mathematical programs and which is also processable by a computer system (Fourer et al., 1990, p. 519). The translation to the algorithm can then be performed by the computer, without the intermediate state of programming (Fourer et al., 1990, p. 520). Because the similarity of the algebraic description of mathematical descriptions and AMPL, this is also mostly a matter of transcription (Fourer et al., 1990, p. 553).

Based on these considerations, the next section describes the formalisation of the KEP Model in the chosen modelling language GMPL. In parallel, the mathematical details of the KEP Model will be presented.

### 3.2 The KEPTool

This section gives a precise mathematical description of the KEP Model to allow for an easy translation to GMPL, which is also given. Thereby, the following conventions are used: Sets will be denoted by capital letters, elements of sets, parameters, variables by lower case letters, and weights are set in Greek letters. For a parameter \( p \) and an element \( k \in K \), \( p(k) \) is denoted by \( p_k \). Further, in this section, the factors of the KEP Model will be referred to as parameters, as this name fits more aptly in the mathematical description. GMPL code will be set in type writer.

An explanation at the beginning: In Section 4.2 some adaptations to the KEP Model induced by the application case will be explained. The KEP Model as pre-
sented and implemented here takes these adaptations into account and thus differs slightly from the description in Thalmann (2012).

First, the input sets to the KEP Model are introduced: Let $K$ be a set of knowledge elements. Further, let $TP$ be a set of topics and $TY$ be a set of types. The function $f_{tp} : K \rightarrow TP$ assigns a topic $tp \in TP$ to every $k \in K$. Similarly, the function $f_{ty} : K \rightarrow TY$ assigns a type $ty \in TY$ to every $k \in K$. The set of adaptation criteria is denoted by $A$. Finally, the set of employees is denoted by $E$. The definition of sets is straightforward in GMPL and is given in the following:

```plaintext
define set KS, dimen 3;
define set K := setof{(k,tp,ty) in KS} k;
define set TP := setof{(k,tp,ty) in KS} tp;
define set TY := setof{(k,tp,ty) in KS} ty;
define set A;
define set E;
```

Here, the set of $KS$ is a set of triples consisting of a knowledge element, a topic, and a type. The last two positions correspond to the assignment of a knowledge element to a topic and type, i.e., $f_{tp}$ and $f_{ty}$. The sets $K$, $TP$ and $TY$ are projections of $KS$ on the sets knowledge elements, topics and types, respectively. The data sets are given in the csv format. For example, $KS$ has to be given in $KNOWLEDGE_ELEMENTS.csv$. The structure of $KNOWLEDGE_ELEMENTS.csv$ is the following:

```
KNOWLEDGE_ELEMENT, TOPIC, TYPE
Aachen Theory Camp Video 2, Learning and Practices, Video
...
```

For the input in GLPK via .csv files, and to get an overview of other possible input options, the kind reader is referred to the on-line documentation. In the following an example for the input of $KNOWLEDGE_ELEMENTS.csv$ is given, the remaining .csvs are similar:

```plaintext
table data_ks IN "CSV" "KNOWLEDGE_ELEMENTS.csv" :
define KS <- [KNOWLEDGE_ELEMENT,TOPIC,TYPE];
```

For the GMPL model, next the binary decision variables $x_{k,a,e}$ have to be stated explicitly.

---

8Keep in mind, that blanks are not ignored. The author has learned this in the progress. Also, decimal numbers are written using ".", e.g., $3.147$.
9See en.wikibooks.org/wiki/GLPK/Table_Statement.
var x{k in K, a in A, e in E} binary;

If \( x[k,a,e] \) evaluates to true, i.e., 1, the knowledge element \( k \) should be prepared according to adaptation criterion \( a \) by employee \( e \).

Next, all parameters of the KEP Model are described step by step. An overview of the parameters and weights can be found in Appendix A.1, Table A.1, Table A.2, and Table A.3. Following Thalmann (2012, p. 221), an interval for the parameter range is set. All parameter values are between a lower bound, \( lb \), and an upper bound, \( ub \), i.e., let \( V = \{ x \mid x \in \mathbb{R} \text{ and } lb \leq x \leq ub \} \). The definition of lower and upper bounds is organisation specific (Thalmann, 2012, p. 299). These bounds are easily incorporated with GMPL and are also given in a csv file. Therefore a set of bounds is introduced, which contains the lower bound (\( lb \)) and upper bound (\( ub \)). The corresponding GMPL code is shown in the following.

set B;
param bound{b in B};

The KEP Model allows to weigh the parameters. The weights are treated similarly to the bounds. The set \( W \) contains weights to the for every relevant parameter. Also, the weights are bounded, but between 0 and 1. One may think of this as an percentage of influence between 0 and 100 %.

set W;
param weight{w in W}, >=0, <=1;

The sets \( \text{bound} \) and \( \text{weight} \) will become clearer after the introduction of the next parameter, which they serve to bound and weight. The importance of a knowledge element, \( i_k \in V \), is the sum of the importance of topic, \( i_{tp} \in V \), and importance of type, \( i_{ty} \in V \) (Thalmann, 2012, pp. 174). The decision maker provides an importance of each topic \( tp \in TP \) and type \( ty \in TY \). Weights \( \alpha_{tp}, \alpha_{ty} \in [0,1] \) allow to express the influence of \( i_{tp} \) and \( i_{ty} \) on \( i_k \). The condition \( \alpha_{tp} + \alpha_{ty} = 1 \) guarantees \( i_k \in V \). The importance of a knowledge element is then computed by the following formula:

\[
i_k := \alpha_{tp} \cdot i_{f_{tp}(k)} + \alpha_{ty} \cdot i_{f_{ty}(k)}
\]

The parameters \( i_{tp} \) and \( i_{ty} \) are declared in GMPL next. Thereby the upper and the lower bound, as well as the condition on the weights, are honoured.
param itp{tp in TP} >= bound["lb"], <= bound["ub"];  
param ity{ty in TY} >= bound["lb"], <= bound["ub"];  
check: weight["ity"] + weight["itp"] = 1;  

Unfortunately, GMPL does not support the definition of a computed parameter, such as the parameter \( i_k \). However, this can easily be solved by replacing \( i_k \) by the original definition, i.e., \( \text{weight["itp"]} \times \text{itp[tp]} + \text{weight["ity"]} \times \text{ity[ty]} \), as will become evident in the composition of the parameters in the optimisation function.

For the need for an adaptation task, \( n_a \in V \) the decision maker decides on the need of a preparation task according to an adaptation criterion \( a \in A \) (Thalmann, 2012, pp. 182). The corresponding GMPL declaration is given next.

param n{a in A}, >= bound["lb"], <= bound["ub"];  

The complexity of a knowledge element, \( c_{k,a} \in V \), is the sum of the parameters complexity of topic, \( c_{tp,a} \in V \), and complexity of type, \( c_{ty,a} \in V \) (Thalmann, 2012, pp. 223). Weights \( \gamma_{tp}, \gamma_{ty} \in [0,1] \) express the influence of \( c_{tp,a} \) and \( c_{ty,a} \) on \( c_{k,a} \) and \( \gamma_{tp} + \gamma_{ty} = 1 \) guarantees \( c_{k,a} \in V \). The complexity of a knowledge element is then computed by the following formula:

\[
c_{k,a} := \gamma_{tp} \cdot c_{f_{tp}(k),a} + \gamma_{ty} \cdot c_{f_{ty}(k),a}
\]

The corresponding GMPL declaration of the complexity for topic and type and the condition on the weights is given in the following.

param cmtp{a in A, tp in TP}, >= bound["lb"], <= bound["ub"];  
param cmty{a in A, ty in TY}, >= bound["lb"], <= bound["ub"];  
check: weight["cmtp"] + weight["cmty"] = 1;  

The experience of an employee, \( e_{k,a,e} \in V \), is the sum of the parameters experience of employee with respect to topic, \( e_{tp,e} \in V \), experience of employee with respect to type, \( e_{ty,e} \in V \), and experience of employee with respect to adaptation criterion, \( e_{a,e} \in V \) (Thalmann, 2012, pp. 225). The weights \( \delta_{tp}, \delta_{ty}, \delta_a \in [0,1] \) express the influence of \( e_{tp,e} \), \( e_{ty,e} \) and \( e_{a,e} \) on \( e_{k,a,e} \) and \( \delta_{tp} + \delta_{ty} + \delta_a = 1 \) guarantees \( e_{k,a,e} \in V \). The experience of an employee is then computed by the following formula:

\[
e_{k,a,e} := \delta_{tp} \cdot e_{f_{tp}(k),e} + \delta_{ty} \cdot e_{f_{ty}(k),e} + \delta_a \cdot e_{a,e}
\]

\(^{10}\)See en.wikibooks.org/wiki/GLPK/GMPL_Workarounds.
The corresponding GMPL declaration and the condition on the weights is given in the following.

```plaintext
param eptp{e in E, tp in TP}, >= bound["lb"], <= bound["ub"];
param epty{e in E, ty in TY}, >= bound["lb"], <= bound["ub"];
param epa{e in E, a in A}, >= bound["lb"], <= bound["ub"];
check: weight["eptp"] + weight["epty"] + weight["epa"] = 1
```

The minimal experience of an employee is a parameter for topics, \( \text{metp} \in V \), types, \( \text{mety} \in V \), and adaptation criteria, \( \text{mea} \in V \) (Thalmann, 2012, pp. 226). Differently to the parameters before, this is a constant for all \( ty \in TY, tp \in TP \) and \( a \in A \). Then, for a knowledge element \( k \) and an adaptation criterion \( a \) to be selectable for preparation by the employee \( e \), the following constraints have to hold:

\[
\begin{align*}
\text{ex}_{f_p(k), e} \geq \text{metp} \quad & \text{and} \\
\text{ex}_{f_h(k), e} \geq \text{mety} \quad & \text{and} \\
\text{ex}_{a, e} \geq \text{mea}
\end{align*}
\]

For modelling in GMPL at first the condition on the bounds for \( \text{metp}, \text{mety}, \) and \( \text{mea} \) are checked. The constraints will be discussed later in this section.

```plaintext
check: bound["ub"] >= bound["metp"]
and bound["metp"] >= bound["lb"];
check: bound["ub"] >= bound["mety"]
and bound["mety"] >= bound["lb"];
check: bound["ub"] >= bound["mea"]
and bound["mea"] >= bound["lb"];
```

The tool support, \( \text{ts}_{k,a} \in V \), is determined with respect to types and adaptation criteria, \( \text{ts}_{ty,a} \in V \) (Thalmann, 2012, pp. 227). Then, tool support is defined by the following formula:

\[
\text{ts}_{k,a} := \text{ts}_{f_p(k),a}
\]

In GMPL the tool support is represented by the following parameter.

```plaintext
param ts{a in A, ty in TY}, >= bound["lb"], <= bound["ub"];
```

The expected quality for a knowledge element, \( q_{k,a} \in V \), is determined for topics with respect to adaptation criteria, \( q_{tp,a} \in V \) (Thalmann, 2012, pp. 229) and defined
by the following formula.

\[ q_{k,a} := q_{f_{tp}(k),a} \]

The corresponding GMPL declaration is given in the following.

```plaintext
param q{a in A, ty in TY}, >= bound["lb"], <= bound["ub"];  
```

The maximal feasible level of quality, \( mq_{k,a} \in \{0,1\} \), is determined with respect to types and adaptation criteria, \( mq_{ty,a} \in \{0,1\} \) (Thalmann, 2012, pp. 238). Then, the maximal feasible level of quality is defined by the following formula:

\[ mq_{k,a} := mq_{f_{ty}(k),a} \]

For a knowledge element \( k \) and an adaptation criterion \( a \), to be selectable for preparation, the following has to hold:

\[ \text{if } x_{k,a,e} = 1 \text{ then } mq_{k,a} = 1 \]

The corresponding declaration in GMPL is given here, the constraint will be discussed later on.

```plaintext
param mlq{a in A, ty in TY}, binary;  
```

The potential for reuse, \( r_{k,a} \in V \), with respect to an adaptation criterion is determined by the parameters potential for reuse of topic, \( r_{tp,a} \in V \), and potential for reuse of type, \( r_{ty,a} \in V \). Weights \( \theta_{tp}, \theta_{ty} \in [0,1] \) express the influence of \( r_{tp,a} \) and \( r_{ty,a} \) on \( r_{k,a} \) and \( \theta_{tp} + \theta_{ty} = 1 \) guarantees \( r_{k,a} \in V \). The potential for reuse of a knowledge element is then computed by the following formula:

\[ r_{k,a} := \theta_{tp} \cdot r_{f_{tp}(k),a} + \theta_{ty} \cdot r_{f_{ty}(k),a} \]

The GMPL parameters and the corresponding condition is given by the following:

```plaintext
param rtp{a in A, tp in TP}, >= bound["lb"], <= bound["ub"];  
param rty{a in A, ty in TY}, >= bound["lb"], <= bound["ub"];  
check: weight["rtp"] + weight["rty"] = 1;  
```

The size of a knowledge element, \( s_{k,a} \in V \), is a parameter with respect to an adaptation criterion (Thalmann, 2012, pp. 233). The corresponding GMPL declaration is given in the following.
The feasibility of a preparation, \( f_{k,a} \in \{0,1\} \), is the feasibility for types with respect to adaptation criteria, \( f_{ty,a} \in \{0,1\} \) (Thalmann, 2012, pp. 236). The feasibility of preparation is defined by the following formula:

\[
f_{k,a} := f_{ty(k),a}
\]

Then, for a knowledge element \( k \) and an adaptation criterion to be selectable for preparation, the following has to hold:

\[
\text{if } x_{k,a,e} = 1 \text{ then } f_{k,a} = 1
\]

The declaration of the parameter in GMPL is given now, the constraint will again be discussed later on in this section.

\[
\text{param } f\{a \in A, ty \in TY\} \text{ binary;}
\]

The last parameter is the capacity of an employee, \( cp_e \) (Thalmann, 2012, pp. 279). The decision maker decides on the capacity for each employee \( e \in E \).

\[
\text{param } cp\{e \in E\};
\]

Now, all parameters have been introduced and declared in GMPL. They are given in csv files similar to KNOWLEDGE ELEMENTS.csv discussed earlier.

Finally, all the introduced parameters are combined in the following optimisation problem. As a reminder, the decision variable \( x_{k,a,e} = 1 \) indicates, that the knowledge element \( k \) should be assigned to employee \( e \) to be prepared according to the adaptation criteria \( a \). Otherwise \( x_{k,a,e} = 0 \). Hence, \( x_{k,a,e} \in \{0,1\} \). Again, the parameters in the optimisation function may be weighted. The importance and the need can be weighted by \( \alpha \) and \( \beta \). Hereby, the condition is that \( \alpha + \beta = 1 \). The influence of the effort can be weighed by \( \sigma \), the influence of size by \( \rho \), of complexity by \( \gamma \), of tool support by \( \epsilon \), of expected quality by \( \eta \), of potential for reuse by \( \theta \) and of experience by \( \delta \). It is important that \( \delta \neq 0 \). The two conditions on the weights are also given in GMPL in the following.

\[
\text{check: weight["i"] + weight["n"] = 1;}
\]

\[
\text{check: weight["e"] != 0;}
\]
As a second reminder, the introduced parameters and weights are summarised in Appendix A.1, Table A.1, Table A.2, and Table A.3. These tables might serve as a reference for the following formula:

$$\sum_{e \in E} \sum_{a \in A} \sum_{k \in K} x_{k,a,e} \cdot \left( \alpha \cdot i_k + \beta \cdot n_a \right)$$

$$- \sigma \left( \rho \cdot s_{k,a} \left( \gamma \cdot c_{k,a} \cdot \epsilon \cdot ts_{k,a} \cdot \eta \cdot q_{k,a} \cdot \theta \cdot r_{k,a} \right) \cdot \delta \cdot ex_{k,a,e} \right) \rightarrow \text{max}$$

The above optimisation function is translated to GMPL. To increase readability, in the formula the parameter weight is shortened to $w$.

```plaintext
maximize objective: sum{(k,tp,ty) in KS, a in A, e in E} ( 
  x[k, a, e] 
  * ( 
    w["i"] * ( w["itp"] * itp[tp] + w["ity"] * ity[ty]) 
    + w["n"] * n[a] 
    - w["c"] 
    * ( s[a,k] 
      *(w["cmtp"] * cmtp[a,tp] + w["cmty"] * cmty[a,ty]) 
      * w["ts"] * ts[a,ty] 
      * w["q"] * q[a,ty] 
      * w["r"] * (w["rtp"] * rtp[a,tp] + w["rty"] * rty[a,ty]) 
      * (w["e"] 
        * ( 
          w["eptp"] * eptp[e,tp] 
          + w["epty"]* epty[e,ty] 
          + w["epa"] * epa[e,a] 
        ) 
      ) 
    ) 
  );
```

The optimisation function is subject to several constraints. The first constraint ensures that the capacity for each employee is not exceeded.

$$\text{for all } e \in E : x_{k,a,e} \cdot \left( \rho \cdot s_{k,a} \left( \gamma \cdot c_{k,a} \cdot \epsilon \cdot ts_{k,a} \cdot \eta \cdot q_{k,a} \cdot \theta \cdot r_{k,a} \right) \cdot \delta \cdot ex_{k,a,e} \right) \leq \text{cp}_e$$

This constraint is translated to GMPL. Again, the parameter weight is abbreviated as $w$. 
s.t. capacity \{e \in E\}: \sum_{(k, tp, ty) \in KS, a \in A} (s[a,k] * (w["cmtp"] * cmtp[a,tp] + w["cmy"] * cmy[a,ty]) * w["ts"] * ts[a,ty] * w["q"] * q[a,ty] * w["r"] * (w["rtp"] * rtp[a,tp] + w["rty"] * rty[a,ty]) * (w["e"] * (w["eptp"] * eptp[e,tp] + w["epty"] * epty[e,ty] + w["epa"] * epa[e,a]))) <= cp[e];

The next constraint ensures, that a preparation task gets assigned to one employee at most:

\[ \text{for all } a \in A, k \in K:\sum_{e \in E} x[k, a, e] \leq 1 \]

The constraint translated to GMPL is given in the following.

s.t. common_sense\{a \in A, k \in K\}: \sum_{e \in E} x[k, a, e] \leq 1;

Finally, the constraints already introduced above are considered—the feasibility, minimal level of experience, and maximal level of quality. Therefore, the feasibility constraint is given again.

if \(x_{k,a,e} = 1\) then \(f_{k,a} = 1\)

GMPL does not support the formulation with if. Thus, in the following GMPL code a work-around is employed.

s.t. feasibility
\{(k,tp,ty) \in KS, a \in A, e \in E\}: x[k,a,e] <= f[a,ty];

If 1 is assigned to \(x[k,a,e]\), then \(1 \leq f[a,ty]\) enforces that \(f[a,ty] = 1\). On the other hand, if 0 is assigned to \(x[k,a,e]\) then \(0 \leq f[a,ty]\) is always fulfilled.
The next constraint considers the minimal level of experience of employees and has been introduced before.

\[
\begin{align*}
\text{if } x_{k,a,e} = 1 & \text{ then } \text{ex}_{f_k}(k,e) \geq \text{metp} \text{ and } \\
\text{ex}_{f_k}(k,e) & \geq \text{mety} \text{ and } \\
\text{ex}_{a,e} & \geq \text{mea}
\end{align*}
\]

In GMPL these constraints are implemented by the following code. Again, a work-around is needed, as if is not supported.

\begin{verbatim}
s.t. employee_experience_adatpation_tasks
    \{(k,tp,ty) in KS, a in A, e in E\}: epa[e,a] >= x[k,a,e] * bound["mea"];
s.t. employee_experience_topic
    \{(k,tp,ty) in KS, a in A, e in E\}: eptp[e,tp] >= x[k,a,e] * bound["metp"];
s.t. employee_experience_type
    \{(k,tp,ty) in KS, a in A, e in E\}: epty[e,ty] >= x[k,a,e] * bound["mety"];\end{verbatim}

If 1 is assigned to \(x_{k,a,e}\), then the original condition has to be fulfilled, i.e., \(epa[e,a] \geq 1 \times \text{bound["mea"]}\). On the other hand, if 0 is assigned to \(x_{k,a,e}\) then \(epa[e,a] \geq 0 \times \text{bound["mea"]}\) is always fulfilled for non-negative experience.

The final constraint ensures, that the preparation tasks do not exceed the maximal level of quality:

\[
\text{if } x_{k,a,e} = 1 \text{ then } \text{mq}_{k,a} = 1
\]

Also here a work around, in the same fashion as as for the feasibility constraint, is needed:

\begin{verbatim}
s.t. maximal_quality_level
    \{(k,tp,ty) in KS, a in A, e in E\}: x[k,a,e] <= mlq[a,ty];\end{verbatim}

This completes the mathematical description of the KEP Model. For the GMPL formalisation, a single command remains to be given.
Recall that some adaptations of the KEPM Model due to the application case are explained in Section 4.2. Now differences, not due to the application case, but to the original formulation by Thalmann (2012) are highlighted and justified. As a preparation task for the formalisation of the KEPM Model, the mathematical notation was revised and adapted. The definition of $i$ and $n$ are slightly different from the definition in Thalmann (2012, pp. 174, 182). There, he requests $i, n \in [0, 1]$. This is changed to $i, n \in \mathbb{V}$ as this is more consistent with the definition of the other input parameters, which also are in $\mathbb{V}$. The parameter to indicate the reuse of adaptation tasks according to types of knowledge elements, $r_{ty,a}$, is defined in Thalmann (2012, p. 240). However, it is not included in the final description in Thalmann (2012, p. 278). Thus, a procedure similar to the importance and complexity of topics and types was chosen. This required the introduction of two further weights, i.e., the weight of the reuse of the topic, $\theta_{tp}$, and the weight of the reuse of the type, $\theta_{ty}$ with the additional constraint $\theta_{tp} + \theta_{ty} = 1$. The constraints in Thalmann (2012, pp. 178) needed revision to match with their textual description. Finally, Appendix A.2 sketches some direction towards further considerations regarding the KEPM Model. At the end, some thoughts on the structure of the user interface for the KEPTool are presented. To ease the data input, a graphical user interface was designed and is shown in Figure 3.2. The design elements follow the internal LL User Interface Guidelines. As users are more likely to adopt technology they are familiar with and a tool that is compatible with their other tasks (Sauter, 2010, p. 391), Microsoft Excel is a good choice as a front end, as it is the most common end-user tool for DSS development (Turban et al., 2011, p. 80). Moreover, spreadsheets are
robust and easily understandable for model-driven DSSs (Power and Sharda, 2007, p. 1044). The DSS needs to be simple to access to the decision maker (Sauter, 2010, p. 375).

3.3 Summary

This chapter first motivated the selection of the GLPK, but in particular the stand alone glpsol solver, but more importantly, the modelling language for implementing the KEP Model as informally introduced in Section 2.1. Choosing the declarative GMPL modelling language supported for modelling the KEP Model very closely related to to its mathematical description making it less error prone. But moreover it allows for modularity. The solver might be exchanged easily by any other solver accepting GMPL, or AMPL, as an input language. The data input and output is achieved via csv files, which have very low overhead and are easily maintained and integrated with other applications.

In the second part of this chapter, the translation from a precise mathematical description of the KEP Model to GMPL code is described step by step. This translation was for the most part straight forward. Thereby some easy work arounds to bypass limitations of GMPL were employed. The implementation already took some adaptations to the KEP Model into account, which are motivated by the application case and described in detail in Section 4.2.

In this chapter the first requirement of the research objective is fulfilled: the implementation of the KEP Model, i.e., the KEPTool. This now enables the consecutive application and evaluation of the KEP Model described in the following Chapter 4.
4 Evaluation

This chapter describes the evaluation of the KEP Model and the KEPTool. Section 4.1 describes the overall procedure. Section 4.2 describes the case, i.e., the Layers Theory Camp, and the data collection. Section 4.3 and Section 4.4 describe the collection of ratings for benefits and efforts, respectively. Section 4.5 describes the conducted expert interviews. Finally, Section 4.6 describes the analysis. The chapter is summarised in the last Section 4.7.

4.1 Procedure

Figure 4.1 gives an overview of the general process of applying the KEP Model in the context of the Layers Theory Camp to enable consecutive evaluation. Phase I, the data collection, aims at (1) the collection of suitable data sets, e.g., knowledge elements or adaptation criteria, and (2) the collection of ratings for the factors of the KEP Model. The collection of suitable data sets is described in Section 4.2. To determine ratings for the benefits for the KEPTool, a survey among the stakeholders of the Layers Theory Camp was conducted, as described in Section 4.3. The objectives of the survey are to arrive at average ratings for factors influencing the benefits. The ratings of effort are less strategic and less company-specific (Thalmann, 2012, p. 302). Thus, these ratings will be collected by experts interviews to save rating effort. This is explained in detail in Section 4.4.

Phase II is the application of the KEP Model. The KEP Model should be applied to the data sets and with the ratings collected in Phase I. This required the implementation of the KEP Model in a suitable fashion, as described in Chapter 3,
and led to the KEPTool. The application of the KEPTool in a concrete setting enables a consecutive evaluation of the output—the proposal the KEPTool computed for the Layers Theory Camp.

Phase I and Phase II serve as basis for Phase III and the research objective of this thesis: the evaluation of the KEP Model and the KEPTool. For conducting a formative evaluation, experts within the LL project were interviewed which is described in detail in Section 4.5.

In the following, the individual tasks for the evaluation and the expected results are related to the research objective from Chapter 1. For sub-objective 1, the experts evaluate the proposal the KEPTool computed for the Layers Theory Camp. The proposal is based on the collaborative ratings collected in the survey. As the KEPTool is applied in a setting the experts can relate to and with a concrete proposal, the experts can argue in detail about parts of the proposal. Further, they are presented with a second proposal, which was computed based on their individual ratings collected in the survey. This is to contrast their personalised proposal against the proposal computed based on the collaborative ratings of benefits. As the experts have participated in the survey, a further question aims at the evaluation of the rating procedure of the benefits, i.e., sub-objective 2. Also, the experts are asked to evaluate the factors influencing the benefits and efforts in the KEP Model and to identify further potential factors, or aspects of factors, which could be incorporated in the KEP Model, which aims at sub-objective 3. Similarly, for sub-objective 4, the experts are asked for the weights balancing the factors in the KEP Model. The last two sub-objectives are concerned with future developments of the KEPTool. The experts are presented with the functionality of the KEPTool. Thus, it is expected that they could provide requirements for the graphical user interface, i.e., sub-objective 5, and future application scenarios of the KEPTool, i.e., sub-objective 6.

### 4.2 Case Description and Data Collection

This section starts with the description of the case: The Layers Theory Camp. Then it is concerned with the collection of the input data sets to the KEP Model: The knowledge elements, adaptation criteria, and employees.

The Layers Theory Camp is an initiative within the LL project. In course of the Layers Theory Camp many artefacts, like wiki articles, presentations, videos and more have been created. A meeting of the Layers Theory Camp took place between 27th March 2014, 13:00 and 28th March 2014, 11:00 at Rheinisch-Westfälische Tech-
nische Hochschule Aachen. In total, 30 persons from the LL project participated, two of them remotely. The purpose of the meeting was to “arrive at an understanding of informal learning, its support and scaling with technologies”, and to “establish a theoretical connection to the Social Semantic Server”, to further “guide the design of tools” and “allow analysis of data from the empirical studies”.

The artefacts created at the Layers Theory Camp can be classified as knowledge elements following the definition in Section 2.1. These created knowledge elements will serve as input to the KEPM. This selection has several benefits: The knowledge elements are known and accessible to the participants of the Layers Theory Camp. The participants can relate to them and have a stake within the Layers Theory Camp. Thus, the participants are ideal candidates for a consecutive evaluation of the KEPM. In course of the Layers Theory Camp, in the internal LL wiki, a wiki page was collaboratively created and developed—the Layers Theory Camp wiki page. A screen shot of this wiki page can be found in Appendix A.3, Figure A.1. The Layers Theory Camp wiki page served as starting point for the gathering of knowledge elements. Therefore, all links in this wiki page, leading to knowledge elements, were followed once. Through this procedure, 61 knowledge elements were collected. Three knowledge elements were not accessible or damaged. Hence, the final data set contained 58 knowledge elements. All knowledge elements are accessible from within the LL wiki. The knowledge elements are listed in Appendix A.3, Table A.4. The set of knowledge elements corresponds to the set $K$ in the mathematical description of the KEPM in Section 3.2.

In the next step, as required by the KEPM, topics and types have to be assigned to the collected knowledge elements. For most knowledge elements, the assignment of topics could be derived from the structure of the Layers Theory Camp wiki page. That is, the sections of the wiki page gave a clear indication of the topic a knowledge element should be assigned. Two knowledge elements were not explicitly categorised in a section, but by sighting the content, it was possible to assign them to existing topics. Further, some knowledge elements concerned the organisation of the Layers Theory Camp. Those were assigned the topic Organisation of the Theory Camp. The list of topics, sorted alphabetically, can be found in Table 4.1. These topics are the set $TP$ in the mathematical description of the KEPM in Section 3.2.

---

1See learning-layers.eu/events/aachen-theory-camp.
3See htk.tlu.ee/layers/MW/index.php/Layers_Theory_Camp.
4A digital copy is available upon request from the author.
Table 4.1: Topics of the knowledge elements from the Layers Theory Camp (TP).

The types have been assigned based on the data formats of the knowledge elements. The identified types are listed in Table 4.2 and are briefly described in the following. An article contains text and figures. A flash meeting\(^5\) contains an audio and video stream, as well as meeting minutes, which incorporate a chat protocol. A video has a video and an audio track. A spreadsheet is organised along rows and columns. Each cell can contain text, but also figures. A presentation contains, similar to articles, text and figures organised in slides. A wiki page is similar to an article and can contain text and figures. These types are the set \(TY\) in the mathematical description of the KEP Model in Section 3.2.

Table 4.2: Types of the knowledge elements from the Layers Theory Camp (TY).

The definition of knowledge elements in Section 2.1 would allow a more fine grained description of knowledge elements in this setting. For example, each figure in an article could qualify as a distinct knowledge element. In this context a lower granu-

\(^5\)See flashmeeting.open.ac.uk.
larity was chosen to keep the amount of knowledge elements feasible for the decision makers and the KEPTool. This choice, and other measurements to reduce the rating effort, will be discussed next. However, the individual parts a knowledge element will be considered for estimating the size of a knowledge element, which is discussed in Section 4.4. Finally, on the knowledge elements the following assumption is imposed: The knowledge elements are adaptable without any legal or technical constraints. This encompasses, for example, that no copyrights are breached or that for a PDF file exported from a word processing application the editable original is available. This is a reasonable assumption, as the knowledge elements were created by the participants in the Layers Theory Camp. Thus, considerations concerning these restrictions are neglected.

The set of knowledge elements is the first of three input sets in the KEP Model. Now the next two sets, the adaptation criteria and the employees, are considered. For this, first the effort for rating, and limitations of the KEPTool, will be inspected.

For a successful application of the KEP Model, the decision makers have to take many decisions. Precisely, if $|\cdot|$ denotes the cardinality of a set and $K$ the set of knowledge elements, $TP$ and $TY$ the sets of topics and types, $A$ the adaptation criteria, which can be performed manually or automatically, i.e., $M = \{\text{man, auto}\}$, and $E$ the set of employees, this amounts to $|K| \cdot |A \times M| \cdot |E|$ decision variables in the optimisation model. The decision maker has to determine the following number of ratings.

$$\text{number of ratings} = |A \times M| + |E| \cdot 2 + |TP| + |TY| + |A \times M| \cdot |K| + |A \times M| \cdot |TY| \cdot 5$$

$$+ |A \times M| \cdot |TP| \cdot 2 + |E| \cdot |TP| + |E| \cdot |TY| + |E| \cdot |A \times M|$$

In a setting with 2 employees, 11 topics, 6 types, 56 knowledge elements and 13 adaptation criteria, this amounts to 2941 decisions, which gives rise to $2^{2912}$ combinations. Assuming each decision takes 10 seconds, this amounts to a rating time of 8 hours, 10 minutes and 10 seconds. Additionally, the weights and minimal levels of experience have to be set, amounting to another 14 decisions. Albeit this effort spent in rating can be feasible in a context where the ratings can be reused, it is not feasible for an initial implementation and evaluation of the KEP Model. Further, the implementation of the model is not optimised towards performance and also limitations of the solver in the KEPTool have to be considered. Thus, to reduce the amount of decisions several options are considered.
1. *Reduce the amount of employees:* This reduces the rating effort and is also beneficial for the solver, as the amount of decision variables is dependent on \( E \).

2. *Reduce the amount of adaptation criteria:* This reduces the rating effort and is also beneficial for the solver.

3. *Reduce the amount of topics and types:* This reduces the rating effort for the decision maker, but has no influence on the decision variables.

4. *Manual and Automatic Preparation:* When the manual and automatic preparation, i.e., \( M \), is dropped, each adaptation criterion is only considered once. This is beneficial for the rating effort and the solver.

Option 1 severely limits the KEP Model as the assignment of tasks to employees is a vital feature. Thus, this is not adopted. Also Option 3 is problematic, as this requires a selection and modification of the assignments of knowledge elements to topics and types. It is unclear, how this selection and modification can be achieved without introducing a bias.

This leaves Option 2 and Option 4. First, the distinction of manual or automatic preparation is dropped, which then is a limitation of the evaluation and discussed in Chapter 6. As already stated in Section 3.2, the formalisation of the KEP Model has been subject to some modifications, and this describes one of them—the distinction between manual and automatic preparation tasks is not included.

The selection of adaptation criteria can be achieved without corrupting the set of knowledge elements. Thus, five adaptation criteria from Thalmann (2014) are selected. The five selected adaptation criteria are listed in Table 4.3. In the first column the name and a short description of each adaptation criterion is given, whereby the second column provides an illustrating example.

The selection was achieved in discussion with a senior member of the LL project, who is also a participant in the Layers Theory Camp. The selection criteria were the relevance to the LL project and the Layers Theory Camp. Because the LL project is concerned with learning, *didactical approach, presentation preferences, and previous knowledge* were selected. A further focus of the LL project is the integration of different, small scale devices, thus *device requirements* was selected. Finally, as an European project spanning different nations, also *language* is an important criterion. This then is the set \( A \) in the mathematical description of the KEP Model in Section 3.2.
<table>
<thead>
<tr>
<th><strong>NAME AND DESCRIPTION</strong></th>
<th><strong>EXAMPLE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Device Requirements: technical characteristics of hardware and basic software that is relevant for accessing the system</td>
<td>A user accesses the system with a mobile device, having a small screen resolution. Thus, only versions that fit that resolution will be delivered.</td>
</tr>
<tr>
<td>2  Didactical Approach: methods considering users preferences and cognitive abilities during learning</td>
<td>A user could be classified as an “implementer” and consequently this user is given resources that are enriched with practical examples.</td>
</tr>
<tr>
<td>3  Language: ability or preference of a user for the language that is used for content delivery</td>
<td>A user speaks only Spanish. She thus is given only the Spanish language version of the knowledge element.</td>
</tr>
<tr>
<td>4  Presentation Preferences: preferences for the style in which contents are delivered</td>
<td>A user prefers very large fonts and red colours. The content is thus rendered with large fonts and a red coloured layout.</td>
</tr>
<tr>
<td>5  Previous Knowledge: knowledge of the user, acquired in the past and relevant for using the system, which has to be considered for the information provision</td>
<td>A user has a technical background and good knowledge of jargon. The user thus gets a version of a technical report without explanations of the basic terms.</td>
</tr>
</tbody>
</table>

Table 4.3: Selected adaptation criteria (A) taken from Thalmann (2014, pp. 54).

As an attempt to counteract the limitation of selecting only a subset of the adaptation criteria, an open question for further adaptation criteria was incorporated in the survey among the stakeholders of the Layers Theory Camp. Therefore, more details are given in Section 4.3. These restrictions reduce the rating effort to 610 decisions, which results in an estimated rating effort of 1 hour 41 minutes and 40 seconds.

Finally, the last input data set is the set of employees. The KEP Model assigns employees to tasks. As the Layers Theory Camp is part of the Layers Deliverable D2.1 and the university of Innsbruck (UIBK) is responsible for it, two employees from the UIBK team were assumed to be charged with the preparation tasks. The two employees have been employed part-time in the LL project for at least half a year. Pseudonyms for them are listed in Table 4.4 and correspond to the set E in the KEP Model in Section 3.2. To sum up, so far the input sets for the KEP Model have been set: the knowledge elements with their topics (Table 4.1) and types (Table 4.2).
the adaptation criteria (Table 4.3), and the employees (Table 4.4). In the next two sections, the rating of the parameters of the KEP Model are described. Hereby a distinction is made between the ratings of effort and the ratings of benefits. The ratings of benefits, i.e., the importance of topic and type ($i_{tp}, i_{ty}$) and the need of an adaptation criterion ($n_a$) are strategic and company specific (Thalmann, 2012, p. 302). Thus, to raise awareness of the KEPTool and foster the acceptance of the solution recommended by the KEPTool a survey was distributed among the stakeholders of the Layers Theory Camp. This is described in detail in the next Section 4.3. The ratings of the efforts are less strategic and thus expert interviews were conducted. This is described in detail in Section 4.4.

### 4.3 Rating of Benefits

To determine the rating of benefits for the KEPTool, a survey among the stakeholders in the Layers Theory Camp was conducted. The procedure and the results are described in this section.

Specific objectives are vital for the success of a survey (Fink, 1995b, p. 5). The objectives for this survey are to obtain average ratings for

1. the importance of topics ($i_{tp}$),
2. the importance of types ($i_{ty}$),
3. the need of adaptation criteria ($n_a$).

Further objectives are the collection of additional adaptation criteria and the identification of respondents, who are interested in the evaluation of the KEPTool.

The survey was conducted in the form of a self-administered questionnaire. For a self-administered questionnaire, Bourque et al. (1995, p. 24) recommend to assess (1) the literacy level of the respondents, (2) the motivation level of the respondents, and, (3) whether the data collection is amenable using a questionnaire. The respondents of the questionnaire are researchers in the LL project. They will receive

<table>
<thead>
<tr>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Alice</td>
</tr>
<tr>
<td>2 Bob</td>
</tr>
</tbody>
</table>

Table 4.4: Pseudonymous for the employees (E).
the questionnaire via the internal LL mailing list, which currently has 83 members. Thus, (1) should not pose a problem. The motivation of the respondents, i.e., the assessment of (2), is crucial (Fink, 1995b, p. 38). As the survey is concerned with the Layers Theory Camp, which is part of the research project the respondents are employed in, a sufficient level of motivation and background information can be assumed. Concerning (3), the objectives of and questions in the survey are succinct and focused and can be covered in a questionnaire (Bourque et al., 1995, pp. 26).

Motivation is particularly important for self-administered questionnaires (Bourque et al., 1995, p. 16). Part of motivating the participant goes towards the cover letter. The e-mail cover letter followed the guidelines provided by Bourque et al. (1995, pp. 121) and Leiner (2014): The purpose of the study was stated, the return date and procedure were specified, an estimation of the time requirements for completion was given. The cover letter is available in Appendix A.4.

The questionnaire was initially available from 12th September to 19th September 2014 and could easily be accessed by a public URL to have a low entry barrier. Follow up attempts are important to the study (Bourque et al., 1995, p. 158). Especially to enhance the response rate of a self-administered questionnaires, several measures should be taken, including pre-mailing and follow-up contacts (Bourque et al., 1995, p. 15). The planned survey was introduced in the a Work Package Leader Call within the LL project 2 weeks prior to conduction. After the end of the survey, on 19th September an e-mail reminder was sent out and the period for participation was extended to 29th September 2014. The survey was also promoted in course of a LL project meeting in Tallinn between 24th September and 26th September. At the end of this meeting, another e-mail reminder was sent out with a presentation of the intermediate results and a call for further participation. The initial and follow-up e-mails were sent by a senior member of the LL project. This is recommended, to have a positive name recognition for the respondents (Bourque et al., 1995, p. 106).

The questionnaire was implemented with the software SoSci Survey (Leiner, 2014). SoSci Survey is a cloud solution for administering on-line questionnaires. For academic use the service is free of charge. Furthermore, the server, software, and operation are located in Germany and are adherent to German privacy laws. Figure 4.2 shows a screen shot of the second page of the survey.

Prior to data collection, a pre-test of the questionnaire was performed to determine whether the questions and instructions are understood and the response

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categories are comprehensive (Bourque et al., 1995, p. 89). The on-line pre-test was conducted between the 10th September and the 12th September 2014 with the support of SoSci Survey, which provides functionality to conduct a pre-test8. In total, five participants reviewed the questionnaire and provided comments. Among the participants were both experts with experience in the creation of surveys and potential respondents, as recommended by Fink (1995a, p. 25) and Bourque et al. (1995, p. 89). The participants uncovered minor problems with unclear or too short descriptions and scales, not introduced acronyms, and orthographic and layout issues. Unclear comments were discussed, and, if possible, the comments were incorporated immediately throughout the pre-test phase. All comments could be addressed and no severe problems were found. To ensure technical correctness, SoSci Survey supports and recommends to perform a technical function test9. This was performed according to instructions prior to the release. The complete questionnaire can be found in Appendix A.4.

In total 21 participants replied, of which 18 persons attended the Layers Theory Camp in Aachen10. The background of the respondents was characterised with three

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10In total, 30 persons attended the meeting.
I attended the Layers Theory Camp in Aachen in person or remotely. 18
I prepared content for the Layers Theory Camp. 16
I was involved in the organisation of the Layers Theory Camp. 6
I actively followed the developments of the Layers Theory Camp. 16
I hardly followed the developments of the Layers Theory Camp. 2
Other 2

<table>
<thead>
<tr>
<th>Statement</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>I attended the Layers Theory Camp in Aachen in person or remotely.</td>
<td>18</td>
</tr>
<tr>
<td>I prepared content for the Layers Theory Camp.</td>
<td>16</td>
</tr>
<tr>
<td>I was involved in the organisation of the Layers Theory Camp.</td>
<td>6</td>
</tr>
<tr>
<td>I actively followed the developments of the Layers Theory Camp.</td>
<td>16</td>
</tr>
<tr>
<td>I hardly followed the developments of the Layers Theory Camp.</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4.5: Responses to involvement in the Layers Theory Camp.

I know the artefacts. 14
I have a general idea about the artefacts. 5
I am uninformed about the artefacts. 1
Other 1

<table>
<thead>
<tr>
<th>Statement</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know the artefacts.</td>
<td>14</td>
</tr>
<tr>
<td>I have a general idea about the artefacts.</td>
<td>5</td>
</tr>
<tr>
<td>I am uninformed about the artefacts.</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4.6: Responses to familiarity with the knowledge elements.

questions about their role in the LL project, their involvement in the Layers Theory
Camp, and their familiarity with the artefacts, i.e., knowledge elements, created at
the Layers Theory Camp.

The survey was completed by 20 persons, who classified themselves as research
partner, 5 persons, who classified themselves as technical partner, and 3 persons, who
classified themselves as application partner. Table 4.5 shows the involvement of the
respondents in the Layers Theory Camp. The majority of the respondents attended
the Layers Theory Camp in Aachen (18) and actively follow the developments (16).
One person added “presentation” in the category Other, and one person said “I
design some of the actions and introduced them”.

Table 4.6 shows the familiarity of the respondents with the artefacts of the Layers
Theory Camp. Out of the 21 respondents, most know the artefacts or have a general
idea (19). One person criticises in the Other category: “I dont think they cshould
be decribed [sic] as artefacts”.

The ratings for the importance of topics, types, and the need for adaptation cri-
teria were determined with closed questions. This is justified as the objective is to
rate the items (Fink, 1995a, p. 34), and further this enables statistic analysis of the
responses (Fink, 1995a, p. 33). The items were rated on a Likert-scale from 7 (defi-
nitely important) to 1 (definitely not important), and additionally the respondents
could refrain from answering by checking “I don’t know”. In Table 4.7, Table 4.8,
Table 4.7: Ratings for the importance of topics (i_{tp}).

<table>
<thead>
<tr>
<th>Topic</th>
<th>AVG</th>
<th>SD</th>
<th>Md</th>
<th>Min</th>
<th>Max</th>
<th>Idk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Claims Matrix for Documenting Design and Empirical Work</td>
<td>5.75</td>
<td>1.44</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>2 Collective and Networked Learning Theories</td>
<td>5.67</td>
<td>1.28</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>3 Generation of Meaning</td>
<td>4.77</td>
<td>1.48</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>4 Integrated Scaffolding Concept</td>
<td>5.06</td>
<td>1.22</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>5 Knowledge Representation</td>
<td>5.22</td>
<td>1.18</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>6 Learning and Practices</td>
<td>6.00</td>
<td>0.93</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>7 Organisation of the Theory Camp</td>
<td>4.41</td>
<td>1.46</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>8 Organisational Learning</td>
<td>4.76</td>
<td>1.93</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>9 Models Used in Other Projects</td>
<td>5.43</td>
<td>1.26</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>10 Research and Design Methods</td>
<td>5.10</td>
<td>1.55</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>11 Social Semantic Server</td>
<td>5.61</td>
<td>1.38</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 4.8: Ratings for the importance of types (i_{ty}).

<table>
<thead>
<tr>
<th>Type</th>
<th>AVG</th>
<th>SD</th>
<th>Md</th>
<th>Min</th>
<th>Max</th>
<th>Idk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Article</td>
<td>5.81</td>
<td>1.14</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>2 Flash Meeting</td>
<td>5.05</td>
<td>1.73</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>3 Presentation</td>
<td>5.62</td>
<td>1.36</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>4 Spreadsheet</td>
<td>4.25</td>
<td>1.37</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>5 Video</td>
<td>5.20</td>
<td>1.69</td>
<td>6</td>
<td>1</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>6 Wiki Page</td>
<td>5.71</td>
<td>1.28</td>
<td>6</td>
<td>2</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4.9 shows the results of the survey for the importance of the topics (i_{tp}) from Table 4.1. Table 4.8 shows the results for the importance of types (i_{ty}) from Table 4.2. Table 4.9 shows the results for the need of adaptation criteria (n_{a}) from Table 4.3. From these results, the Avg will serve as input to the KEPTool for the respective parameter. This is chosen, rather than the median, as the KEP Model can handle non-integer parameters, and here the small differences in the ratings are preserved.

The questionnaire also included a question to identify further adaptation criteria.
<table>
<thead>
<tr>
<th>ADAPTATION CRITERION</th>
<th>AVG</th>
<th>SD</th>
<th>MD</th>
<th>MIN</th>
<th>MAX</th>
<th>IDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1    Device Requirements</td>
<td>4,76</td>
<td>1,80</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>2    Didactical Approach</td>
<td>6,00</td>
<td>0,86</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>3    Language</td>
<td>5,06</td>
<td>1,68</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>4    Presentation Preferences</td>
<td>4,06</td>
<td>1,83</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>5    Previous Knowledge</td>
<td>6,06</td>
<td>1,08</td>
<td>6,5</td>
<td>4</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 4.9: Ratings for the need of adaptation criteria ($n_a$).

This was formulated as an open question to allow a free response and enable the collection of unanticipated answers (Fink, 1995a, p. 32). In total, five persons entered a statement. Two of the statements do not respond to the asked question, but fit very well with the evaluation of the KEP Model, and will thus be discussed in Chapter 4.

The statements concerning potential further adaptation criteria are discussed in the following. The first statement is “Used Tools Integration: All companies and employees still use digital tools (e.g. e-mail, camera, sms, excel-sheets . . . ). New tools should integrate them if possible and senseful. Additionally new tools must have really needed and senseful additional functions”. This statement is more concerned with tools to be developed in the LL project than with the adaptation of the present knowledge elements. Interesting is the statement’s focus on integration of different tools. This strengthens the adaptation criterion device requirements, where a knowledge element should be adapted to several devices, and potentially tools. The two last statements are concerned with a more holistic view on knowledge elements: “We need to scaffold understanding of Theory Camp outputs/outcomes. That is what Layers is about, no?”, and “Relation between artefacts and how they fit to an overall view”. These two statements relate the knowledge elements among each other, a functionality that is currently not supported by the KEP Model, but might be an interesting extension.

### 4.4 Rating of Effort

In this section the rating of effort is described. As noted by Thalmann (2012, p. 311), the “procedure for determining the effort should be investigated in regard to real world cases”. He further notes, that procedures to reduce the rating effort should be explored.

For the rating of efforts, some inspection of the factors determining the effort is required. First, the constraint concerning the capacity of the employees in the KEP...
Model is inspected. The formula for expressing the efforts after Thalmann (2012, p. 270) is shown in the following:\footnote{The weighing factors are left out for simplification.}

\[
\sum_{a \in A} \sum_{k \in K} x_{k,a,e} \cdot \frac{s_{k,a}(c_{k,a} - ts_{k,a} + q_{k,a} - r_{k,a})}{\text{ex}_{k,a,e}} \leq c_{p_e} / \text{time}
\]

If the factor in \(c_{p_e}\) has time as unit, e.g., working hours, the term on the left should also be denoted by time. If the size \(s_{k,a}\) also denotes the (expected) working hours, then \(c_{k,a}, ts_{k,a}, q_{k,a}, r_{k,a}\) and \(\text{ex}_{k,a,e}\) are factors prolonging or shortening the expected working hours. To give an example: An article has to be translated to another language. The article has 1000 words, where the expected working hours are rated as 2, i.e., \(s_{k,a} = 2\). Then, because the topic of the article is complex, one rates a prolonging of the working hours by twice of the time, i.e., \(c_{k,a} = 2\). But, as a good on-line dictionary is available, this takes off a quarter of the expected time, i.e., \(ts_{k,a} = \frac{3}{4}\). The other factors are assumed not to influence the working hours, i.e., they are set to 1.

Then, for rating \(c_{k,a}, ts_{k,a}, q_{k,a}, r_{k,a}\), and \(\text{ex}_{k,a,e}\) the question is: By which factor would the working time increase/decrease considering the complexity, tool support, expected quality, reuse, experience of the employee? But if the values of the factors are inserted directly in the above formula the following happens. Then, \(c_{k,a} + ts_{k,a}\) leads to a factor of \(\frac{5}{4}\), i.e., a expected working time of \(2 \cdot \frac{5}{4} = 3.5\). The expected result would be \(c_{k,a}\) doubles the working time, i.e., the expected working time is 4.

Then, because of the tool support, a quarter of the time can be saved, resulting in a total working time of 3. Thus, the KEP Model has to be changed in so far as the factors are not added up, but multiplied.

Following these observations the following is imposed upon the factors: the size of a knowledge element \((s_{k,a})\) with respect to an adaptation criterion determines the expected working hours, without regard to its topic or type. These are brought in by factors rated by the experts.

This motivates the second modification incorporated in the implementation of the KEP Model in Section 3.2. That is, in contrast to the original formulation of the KEP Model in Thalmann (2012), the factors in the KEP Model are not additive, but multiplicative.

To determine the size of a knowledge element, a bottom-up estimation, similar to the approach by Mendes et al. (2001, pp. 50), will be conducted. Therefore the
lowest level parts of a knowledge element will be rated and combined to a higher level estimate. As already described in Section 4.2, knowledge elements can be split into smaller parts. To then rate the size of a knowledge element, the preparation time an employee needs for preparation with respect to an adaptation criterion is estimated. For example, it is estimated how long an employee needs to prepare 250 words according to ‘language’. Then, the time needed for the individual parts are scaled for each knowledge element, e.g., an article consists of 4 figures and 458 words. The time needed for this is computed by scaling the estimation from the standardised parts, which can be found in Table 4.10. This is similar to the approach by Mendes et al. (2001, p. 53), where they rate the complexity of a web-page based on the number of e.g., links, graphics, texts and videos, and then transfer the metrics to the combined web-page.

The ratings for these standardised parts were performed by the two employees of UIBK introduced in Section 4.2. They determined the ratings collaboratively in discussion and could agree on all the ratings. To this end, they were asked the following question, where ⟨Standard Unit⟩ and ⟨Adaptation Criterion⟩ are instantiated to each standard unit in Table 4.10 and adaptation criterion in Table 4.3.

**Question.** For preparing a ⟨Standard Unit⟩ with respect to ⟨Adaptation Criterion⟩ a typical employee needs ____ minutes?

Example. For preparing a Slide with respect to Presentation Preferences a typical employee needs 15 minutes.

The results of this rating is given in Appendix A.3, Table A.5. Based on the rating for each knowledge element in Table A.4 the size was computed by the procedure as described before. The knowledge elements were investigated manually, an although it was feasible for this set, it hardly seems feasible for a larger set. A solution towards automation, can be based on *meta data*, as already noted by Thalmann (2012, pp. 202). A succinct definition of meta data is given by, e.g., Prothman (2000, p. 20):

<table>
<thead>
<tr>
<th>PART</th>
<th>STANDARD UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text</td>
<td>250 words (approx. half A4 page)</td>
</tr>
<tr>
<td>Video</td>
<td>5 minutes including audio track</td>
</tr>
<tr>
<td>Spreadsheet cells with text content</td>
<td>$5 \times 5$ cells (with text content)</td>
</tr>
<tr>
<td>Slide</td>
<td>1 slide</td>
</tr>
<tr>
<td>Figure</td>
<td>1 figure</td>
</tr>
</tbody>
</table>

Table 4.10: Parts of knowledge elements and their defined standard unit.
“Meta data is data about data”. For the knowledge elements considered in the KEP Model semantic meta data, which gives the purpose and meaning of the data, and quality media data, to allow qualitative analysis and reprocessing the data, would be required (Prothman, 2000, p. 20). The meta data should be derived from and change with the content (Smith and Schirling, 2006, p. 84). Unfortunately, it is hard to find a meta data standard for multimedia content to match all the expectations of an organisation (Sheriff et al., 2011, p. 157), thus a combination of standards may achieve better results (Hirwade, 2011, p. 24), but is not unproblematic, due to overlapping, different structure, or vocabulary and synonyms (Brut et al., 2009, p. 2).

A comprehensive overview over meta data standards, “Glossary of Metadata Standards\(^\text{12}\)”, has been produced by Jenn Riley. Of interest for the KEP Model may be, for example, the Dublin Core, the Qualified Dublin Core, or the IEEE/LOM standard. Unfortunately, the knowledge elements created in the Layers Theory Camp were not equipped with meta data, which could have been fostered for an automatic analysis. In course of this thesis, several meta data standards were investigated for applicability, but the full investigation and application of one, or rather, multiple meta data standards was out of scope for this application. However, this initial investigation may be of interest for the future.

The expert interviews for the ratings of efforts were conducted with 4 experts from the LL project. To keep the number of ratings for each expert at a feasible level, the ratings were divided into three parts: ratings related to the topics, which were rated by a domain expert, ratings related to the type, which were rated by a technical expert, and ratings related to experience which were rated by two employees of UIBK. All experts were provided with guidance in form of a summary of the topics, types, and adaptation tasks. This “cheat sheet” is available in Appendix A.3, Figure A.2.

The domain expert was a senior member of the LL project and UIBK, who has good knowledge about the knowledge element of the Layers Theory Camp. To perform the rating, the domain expert was presented with the following questions and examples.

First the complexity of the topics with respect to the different adaptation criteria \(c_{tp_a}\) was determined. In the questions, \langle Topic\rangle and \langle Adaptation Criterion\rangle are instantiated to each topic and adaptation criterion in Table 4.1 and Table 4.3, respectively.

**Question.** Does the complexity of \langle Topic\rangle influence the preparation time with respect to \langle Adaptation Criterion\rangle?

\(^{12}\)See [www.dlib.indiana.edu/~jenlrile/metadatamap](http://www.dlib.indiana.edu/~jenlrile/metadatamap).
No → Please enter 1.
Yes → Instead of 1 hour of work one needs ___ hours.

Examples. Social Semantic Server is a complex topic, so preparing it with respect to Previous Knowledge is difficult. So instead of 1 hour one needs 2.75 hours of work.

The complexity of the topic Research and Design Methods has no influence on the preparation time with respect to Device Requirements.

The results of these ratings, and the following rating of reusability, can be found in the Appendix A.3, in Table A.6. For the rating of the reusability of a topic with respect to the adaptation criterion \((r_{tp,a})\), the following question and examples were provided:

**Question.** Is for \langle Topic \rangle some previous preparation with respect to \langle Adaptation Criterion \rangle available?

No → Please enter 1.
Yes → Instead of 1 hour of work one needs ___ hours.

Example. For preparing Models Used in Other Projects with respect to Previous Knowledge lots of basic definitions are available in accessible documents, hence one needs only 0.4 of the expected time.

The technical expert also has been employed in the LL project for more than a year and has a diploma in media and computer science. An informal Skype interview was conducted to present the context and the questions to the expert. The interview lasted for approximately one hour and was conducted on the 29th of September 2014. The expert was also provided with the guideline in Figure A.2. Moreover, an on-line spreadsheet was prepared to enable the rating process visible for both the expert and the interviewer. The technical expert was asked to rate the complexity of a type with respect to an adaptation criterion \((c_{ty,a})\), the tool support \((ts_{ty,a})\), the expected quality \((q_{ty,a})\), and the maximal feasible level of quality \((mq_{ty,a})\), the feasibility of preparation \((f_{ty,a})\), and the potential for reuse of preparation tasks \((r_{ty,a})\). The ratings the expert provided can be found in Appendix A.5, Table A.7.

First, the complexity of types with respect to adaptation criteria \((c_{ty,a})\) was determined. The expert was therefore given the following question and examples:

**Question.** Does the complexity of \langle Type \rangle influence the preparation time with respect to \langle Adaptation Criterion \rangle?

No → Please enter 1.
Yes → Instead of 1 hour of work one needs ___ hours.

Examples. Video is a complex type, so preparing it with respect to Language is
difficult. So instead of 1 hour one needs 3 hours of work. The complexity of the type Wiki Page has no influence on the preparation time with respect to Device Requirements.

For the rating of tool support (ts_{ty,a}) the following question and examples were provided:

**Question.** Is preparing a \( \langle \text{Type} \rangle \) with respect to \( \langle \text{Adaptation Criterion} \rangle \) by tools, or functionalities within a tool, well supported?

- No \( \rightarrow \) Please enter 1.
- Yes \( \rightarrow \) Instead of 1 hour of work one needs \( \quad \) hours.

Examples. Preparing an Article with respect to Language is well supported (on-line dictionaries). So instead of 1 hour one needs 0.75 hours.

Preparing a Flash Meeting with respect to Didactical Approach is not well supported.

For the rating of expected quality (q_{ty,a}) and the maximal feasible level of quality (m_{ty,a}) it is assumed, that each prepared knowledge element has to be suspect to a subsequent quality control. If such a control is not feasible, the preparation is not desirable. The following question and examples were provided:

**Question.** If the preparation of \( \langle \text{Type} \rangle \) with respect to \( \langle \text{Adaptation Criterion} \rangle \) takes 1 hour, including quality control one needs \( \quad \) hours. Is this feasible?

- No \( \rightarrow \) Please enter 0.
- Yes \( \rightarrow \) Please enter 1.

Examples. For a Video with respect to Device Requirements, one needs about 2.5 hours instead of 1 (because it has to be tested on different devices). This is not feasible (0).

For a Wiki Page with respect to Language, one needs 1.1 hours instead of 1. This is feasible (1).

For the rating of the feasibility of preparation (f_{ty,a}) the following question and examples were provided:

**Question.** Is preparing a \( \langle \text{Type} \rangle \) with respect to \( \langle \text{Adaptation Criterion} \rangle \) feasible, i.e., there is no technical or practical limitation?

- No \( \rightarrow \) Please enter 0.
- Yes \( \rightarrow \) Please enter 1.

Examples. Preparing an Article with respect to Language is feasible (1).

Preparing a Flash Meeting with respect to Device Requirements is not feasible (0), because no software for manipulating Flash Meetings is available.
For the rating of the potential for reuse of preparation tasks \(r_{ty,a}\) the following question and example were provided:

**Question.** Is for \(Type\) some previous preparation with respect to \(Adaptation\) \(Criterion\) available?

No \(\rightarrow\) Please enter 1.

Yes \(\rightarrow\) Instead of 1 hour of work one needs ____ hours.

Example. For preparing a *Spreadsheet* with respect to *Presentation Preferences* style sheets are available, hence one needs only 0.2 of the expected time.

Finally, the remaining ratings concern the experience of the employees Alice and Bob. As discussed in Section 4.2, Alice and Bob are two part-time employees in the LL project from UIBK. The employees were asked to assess their own experience with respect to a topic \(ex_{tp,e}\), with respect to a type \(ex_{ty,e}\), and with respect to an adaptation criterion \(ex_{xa,e}\), the minimal level of experience for topics \(metp\), types \(mety\), and adaptation criteria \(mea\). Therefore, the following question and examples were provided:

**Question.** I have little/much experience with preparing \(Topic, Type, Adaptation\) \(Criterion\). So instead of 1 hour, I would need ____ hours.

Examples. I have little experience with the topic *Integrated Scaffolding Concepts*, so I expect to work 2 (twice) the expected time.

I have much experience with *Spreadsheet*, so I expect to work 0.5 (half) of the expected time.

I have much experience with *Didactical Approach*, so I expect to work 0.75 of the expected time.

The results of their ratings can be found in Appendix A.5, the experience of the employees with respect to topic \(ex_{tp,e}\) in Table A.8, with respect to type \(ex_{ty,e}\) in Table A.9, and with respect to adaptation criterion \(ex_{xa,e}\) in Table A.10.

Finally, the last paragraph of this section is devoted to the ratings, which are missing. The attentive reader will have noticed the absence of the parameters considering the minimal level of experience for topics \(metp\), types \(mety\), and adaptation criteria \(mea\). It was attempted to collect them from the employees who rated the size and their experience. Their rating resulted in some topics or types not being selectable at all, because the rated experience of both employees was too low for selection. Thus, all knowledge elements of this type and topic would have been eliminated from consideration. This however, is due to the limited number of employees, i.e., only two, in this application. Thus, these parameters were set to the minimum
experience such that both employees could be assigned. This minor limitation of the evaluation of the KEP Model avoids confusion by whole topics, types, or adaptation criteria being discarded. More prominently, the weights of the factors were also not rated by the experts. This is a more profound limitation. The weights were set as to not influence the factors, i.e., either to 0.5 or 1, as appropriate. The setting of weights is very sensitive and requires multiple feedback loops, as suggested, e.g., by Maier et al. (2008, pp. 520) This was out of scope for this thesis.

This section ends with the proposal the KEPTool computed for the Layers Theory Camp, which can be seen in Appendix 5.1, Table A.11. The computation is based on the data sets collected in Section 4.2, the collaborative ratings of the benefits in Section 4.3 and the efforts rated by experts from Section 4.4. These served as input to the KEPTool as described in this section. This proposal was presented in the evaluation of the KEP Model and the KEPTool, which is described in the next Chapter 4.

4.5 Preparation of the Interviews

Additionally to prototypical implementations of DSSs, as introduced in Chapter 3, much information can be gained by interviews with users early on in the development process (Sauter, 2010, p. 373). The involvement of users is vital for the evolution of a DSS, as already investigated in Section 2.3. Thus, for the evaluation of the KEP Model and the KEPTool interviews with potential users were conducted. Therefore, in the survey in Section 4.3, the respondents were asked whether they would like to participate in the consecutive evaluation. The interested respondents were then invited to an interview with the invitation in Appendix A.7.

Interviews allow the in-depth exploration of opinions and expectations (Clarke and Dawson, 1999, p. 73). In contrast to questionnaires, they enable to “gain a deeper and richer understanding of the experts’ viewpoints”, and moreover, allow further probing of the answers, if they are unclear (Parboteeah and Jackson, 2011, p. 691). Therefore, structured, or formal, interviews were chosen, which rely on a interview schedule to ask questions in a consistent order and thus, by exposing every respondent to the same questions, the responses are comparable (Clarke and Dawson, 1999, p. 72). The respondents will be asked open-ended questions, where no response choices are offered, to enable them to phrase their own answers (Frey and Oishi, 1995, p. 28) and to elicit qualitative information (Clarke and Dawson, 1999, p. 72). Special care was taken to not predispose the respondents in their
answers and formulate them in a neutral fashion (Frey and Oishi, 1995, p. 69). The questions aim at the opinions, judgements, and values of the respondents, as opposed to their behaviours and actions, and to elicit what they think about the issue at hand (Patton, 2002, p. 354).

For the interviews, an interview guideline was prepared to structure the interview. The guideline supports systematic interviews, to make good use of the limited available time frame, and ensures that all relevant issues are discussed (Patton, 2002, p. 343). However, the guideline and time frames were designed, such that issues of importance of individual respondents can be integrated (Patton, 2002, p. 344). In the following, the guideline for the interviews is given. The interviews were supported by two visual aids. The first aid was a presentation, shared with the respondents via the screen sharing service join.me. Thus, the respondents were guided through the presentation by the interviewer. The aim of the presentation was to structure the interviews, and, more importantly, provide the evaluators an overview over the KEP Model and KEPTool. The presentation can be found in Appendix A.7, Figure A.4. The second visual aid was the proposal computed by the KEPTool for the Layers Theory Camp. Therefore, spreadsheets with the proposal were created on the on-line platform Google drive, which could be easily shared with the evaluators through a public URL.

The interviews were conducted via telephone, more specifically via Skype. This was due to economic, time, and logistic constraints (Holstein and Gubrium, 2003, p. 176). The recording, where the quality and accuracy is vital for the consequent analysis (Clarke and Dawson, 1999, p. 78), could be achieved conveniently with the freeware tool MP3 Skype Recorder. The interview questions were structured into three main parts. Each part was assigned an estimated time slot of 8-10 minutes in the 30 minutes interview.

1. Factors in the KEP Model,
2. Proposal of the KEPTool, and
3. Outlook for the KEPTool

The first part, the factors in the KEP Model, aims at the evaluation of the factors influencing the benefits and efforts in the KEP Model, the identification of further

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13 Available at www.join.me.
14 Available at drive.google.com.
15 Available at www.skype.com.
16 Available at www.voipcallrecording.com.
potential factors, or aspects of factors, and at gaining insight on how the users
performed the ratings for the benefits in the KEPTool. Further the necessity of
weights in the KEP Model is tested. The questions are listed in the following. The
first three questions in the first part concerned the benefits of the KEP Model, and
were asked after a introduction to the KEP Model with the help of the presentation
in Appendix A.7, Figure A.4. In the presentation at slide 5, the benefits were listed,
when the evaluators where asked the following questions.

1.1 Do you consider one of these two factors [importance of topic or type and need
of an adaptation criterion] more important than the other?

1.2 Do you consider another factor representing the benefits important?

1.3 What was your reasoning during the rating of importance and need in the
survey?

The next three questions in the first part considered the efforts in the KEP Model.
In the presentation Appendix A.7, Figure A.4, slide 6 supported the evaluators with
this question.

1.4 Do you consider one factor [complexity of a topic or type, experience of an
employee, tool support, expected quality, and reusability of preparation tasks]
more important than others?

1.5 Do you consider other factors that influence the effort of employees during the
preparation of knowledge elements important?

1.6 Do you consider benefits or effort more important for the decision which knowl-
edge element should be selected for preparation?

Conclusively, the first part aims at the underlying relationships and the factors
which need to be considered as recommended by Sauter (2010, p. 373). Following
Parboteeah and Jackson (2011, p. 691) it is determined whether some parts of the
model are perceived as more important. Also, the rating procedure is investigated.
These questions aim at the Sub-Objectives 2, 3, and 4 as stated in Chapter 1.

The second part presents the proposal the KEPTool computed for the Layers
Theory Camp which was on display for the evaluators in an on-line spreadsheet.
First the proposal with the collaborative rating of the benefits, as described in
Section 4.3, is investigated. The proposal is shown in Appendix A.6, in Table A.11.
Thereby, the following questions are asked to trigger the investigation.
2.1 What is your first impression of the proposal from the KEPTool?

2.2 Is there anything surprising?

2.3 What do you think about the proposal for the collaborative rating?

Additionally, a second proposal was computed individually for each evaluator which was based on their individual ratings collected in the survey. This individual proposal was discussed in a similar fashion to the proposal for the collaborative rating with the following questions. The final question aims at the comparison between the collaborative and individual proposal.

2.4 What is your first impression of the proposal from the KEPTool?

2.5 Is there anything surprising?

2.6 What do you think about the proposal for your rating?

2.7 Which proposal do you consider more valuable?

These questions aim at sub-objective 1 in Chapter 1.

The third and last part of the interview is concerned with the outlook of the KEPTool. Therefore, the value of the proposals, which are discussed in the second part, are investigated on an abstract level. Then the evaluators are asked to transfer the KEPTool to a different application context. Finally, as the graphical user interface is vital for a DSS (cf. Section 2.3), a question is directed towards requirements on the user interface. The questions are given in the following.

3.1 Do you consider the proposal valuable for disseminating the Layers Theory Camp results?

3.2 Can you imagine other situations where the KEPTool could be applied and what could be benefits of applying it?

3.3 Do you see any specific requirements for the user interface for the KEPTool?

These questions aim at sub-objectives 5 and 6 as stated in Chapter 1. Finally, in the time planning of the interview, care was taken to allow for additional responses and issues arisen by the evaluators.

Prior to the interviews, the interview guideline, informing the participant about the context and objective of the interview, the interviewer, the structure, and the questions was sent out to the interviewees (Patton, 2002, p. 407). This interview
guideline can be found in Appendix A.7, Figure A.3. To further prepare the interview, a more detailed guideline for the interviewer was constructed. This detailed guideline covers the introduction of the interview. That is, it restates the purpose of the interview, gives an overview over the schedule and the confidentiality of the participants (Patton, 2002, p. 407). The detailed guideline also gives transition statements between the questions to identify context changes (Frey and Oishi, 1995, p. 104). Further the detailed guideline includes material to respond to potential, anticipated questions and requests, or, wishes for clarification (Clarke and Dawson, 1999, p. 72). Finally, it also incorporates the gratitude statements at the end with the possibility of the respondents to ask questions (Frey and Oishi, 1995, p. 125). The detailed guideline, in English and in German, is available upon request from the author.

An interview is an interaction between the interviewer and the interviewee. As noted by Patton (2002, p. 341), “the quality of the information during an interview is largely dependent on the interviewer”. The interviewer should on the one side establish a rapport with the interviewee, but on the other hand maintain neutrality with respect to the answers (Patton, 2002, p. 365). Thus, in preparation of the interviews and the interviewer, two pre-tests, or pilot tests, were conducted on 2\textsuperscript{nd} and 3\textsuperscript{rd} October 2014. These pre-tests are required for interview agendas developed for the specific study (Mayring, 2014, p. 13). Thereby, one pre-tester, Pre1, is knowledgeable the about Layers Theory Camp and had been exposed to previous presentations about the KEP Model and KEPTool. The second pre-tester, Pre2, was fairly new to the LL project and did not have background knowledge about the KEP Model and the KEPTool, which was ideal to test the introduction and description of it. The pre-tests also included the test of the technical set-up, i.e., the Skype calls, the recording device, the screen sharing, and the Google drive spreadsheet. Further, the tests were performed in English.

After the interviews, a feedback session was conducted. Pre1 noted, that the proposal contained too much information to grasp easily. At that point, the proposal also gave the corresponding topics and types to the knowledge elements, and the benefits and the effort. Thus, less information was conveyed in the proposal to make it easier to comprehend. Further, the explanation and guidance through the proposal was enhanced. Pre2 was “was kind of surprised that we get just a proposal but, ehm, because I think I couldn’t really answer the question because, ehm, the whole pre-process, ehm, because like I didn’t type in like any specification or any requirements”. Thus, before the presentation of the proposal, an additional slide was
introduced in the presentation, Appendix A.7, Figure A.4, Slide 7, which explained the data collection process to the interviewees.

After the pre-test, 6 experts within the LL project have been interviewed. The interviews took place between 6th October and 13th October 2014 and lasted between 40:35 and 22:37 minutes. All the evaluators are researchers from different universities and countries. Thus, most interviews were held in English, but for one, whose native language was also German. The experts indicated their interest of participation in the interview throughout the survey in Section 4.3. Additionally, Pre1 is also a stakeholder in the Layers Theory Camp, and qualifies as an expert and he will be referred to as Ex7 henceforth. Thus, his recorded interview was also analysed. This results in a total of 7 collected interviews.

This immediately leads to the next two questions: the justification of the sampling strategy and the sample size (Mayring, 2014, p. 12). First, the size of the sample is investigated. In general, for interviews a smaller sampling size is likely, which allows some depth in the exploration of opinions and expectations (Clarke and Dawson, 1999, p. 73). Moreover, if the aim of the formative evaluation is not to find statistical differences, but rather to discover areas for improvement, where a large portion can be found with a small sample (Leroy, 2011, pp. 205). A small sample size, does not easily allow for generalisation of results, but it can open and show new directions for research (Patton, 2002, p. 46). For the initial evaluation of the KEP Model and KEPTool, where the interest lies with the identification of improvements and further directions, a relatively small sample size is sufficient. The sampling strategy poses a major limitation for this evaluation. The interviewees indicated their interest in the participation in the interview in the survey collecting the benefits in Section 4.3. Thus, in theory, all participants in the survey, which was sent out to the whole target population, had the possibility to be chosen for the interview. However, only six participants indicated their interest and so they were sampled for the interview. This can be classified as convenience or ad-hoc sampling, which widely restricts the generalisation of the findings (Mayring, 2014, p. 12). While this poses a restriction, the aim of the evaluation lies not with the generalisation of the results.

Next, some biases, which can occur, are discussed and measures taken to mitigate them are described. To avoid bias, the standardising of interviews is important (Leroy, 2011, pp. 184), which has been achieved by a detailed guideline. Further, the interviews were practised beforehand in pre-tests, especially in the non-native language of the interviewer—English (Leroy, 2011, pp. 184). Sampling bias occurs because of the non-random sampling method. As proposed by Leroy (2011, pp. 186),
to counteract this bias, the entire population should be reached out to in an interesting and understandable way, and participation should be convenient. Measures were taken to reach out to the entire population via the survey described in Section 4.3, but the sample for the interviews was drawn from the respondents of the survey only, which limits the randomness of the sample. *Subject-related bias* occurs as a consequence of the subjects participating in a study, and to reduce this bias, the subjects should not form a loyalty or antipathy to the interviewer (Leroy, 2011, pp. 181). Leroy (2011, p. 184) advises to attain a professional and courteous interaction, and for the interviewer to adopt a professional attitude. This was tried to achieve via the detailed interview guideline. Finally, the *experimenter-related bias* is a result of the experimenters behaviour (Leroy, 2011, p. 183). To avoid this, Leroy (2011, p. 205) suggests to “have someone other than the designer or developer conduct the study”. This only happens partly for the evaluation of the KEPCM and the KEPTool. While the interviewer developed the KEPTool, the KEPCM, underlying the KEPTool, was developed by Thalmann (2012).

Finally, the remainder of this section is devoted to the process of making the data of the recorded interviews available for the subsequent analysis in the next Section 4.6—the transcription (Holstein and Gubrium, 2003, p. 267). Good quality transcriptions require good quality recordings (Holstein and Gubrium, 2003, p. 275), i.e., recordings taken in a quiet place free from interruptions (Patton, 2002, p. 382). Special care has been taken to adhere to these suggestions. Transcription is interpretive work and thus the transcriber has to be chosen carefully (Holstein and Gubrium, 2003, p. 278). It is important, that transcribers have a stake in the content. Transcribers, who have no stake in the interviews, may not catch the content or may not judge distinctions as significant (Holstein and Gubrium, 2003, p. 268). This, and cost considerations, led to the most obvious choice of the interviewer herself. In a first phase the interviews have been transcribed as a pure verbatim protocol, i.e., a transcription of word by word where dialectic formulations, fillers, and articulation are kept (Mayring, 2014, p. 45). In a second phase the transcription was re-checked by listening to the the recordings again and to detect potential deviations to the transcriptions.

### 4.6 Data Analysis

This section describes the interpretation and analysis of the collected interviews. The overall aim is making sense of what the experts have said, to look for patterns and
combining and integrating statements (Patton, 2002, p. 380). For this, a qualitative content analysis, as suggested by Mayring (2014), is performed. Qualitative content analysis is a mixed methods approach—the process of assigning categories to text passages is a qualitative-interpretive act, which is followed by content-analytical rules (Mayring, 2014, p. 10).

The first step is the development of a concrete research question to enable the direct relation of the results to the research question (Mayring, 2014, p. 10). This has been stated as research objective at the start of this thesis in Chapter 1.

The central instrument of analysis is the category system (Mayring, 2014, p. 40), where the categories are assigned to parts of the text (Mayring, 2014, p. 51). These units, or *codes*, are used retrieve and categorise similar data chunks (Miles et al., 2013, p. 72). This thesis follows the deductive category assignment suggested by Mayring (2014, pp. 95). Based on the research objectives from Chapter 1 a category system has been developed. In a next step the definition of a coding guideline was performed. Table 4.11 shows the final list of codes in the the first column, followed by a short description in the second column. The third column relates the codes to the questions in the interview guideline from Section 4.5, and the last column shows, where the respective results can be found. This is similar to the method Miles et al. (2013, p. 81) describe for deductive coding, where they state that the codes can be derived from the research questions. To distinguish the codes they will be written in *sans serif*.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Question</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>proposal</td>
<td>statements discussing the proposal of the KEPTool</td>
<td>2.1-2.7, 3.1</td>
<td>5.1</td>
</tr>
<tr>
<td>factor</td>
<td>statements suggesting new factors or discussing the present factors</td>
<td>1.2, 1.5</td>
<td>5.2</td>
</tr>
<tr>
<td>weight</td>
<td>statements concerning the reasoning how the weight could be instantiated</td>
<td>1.1, 1.4, 1.6</td>
<td>5.3</td>
</tr>
<tr>
<td>rating procedure</td>
<td>statements concerning the procedure of rating the benefits</td>
<td>1.3</td>
<td>5.4</td>
</tr>
<tr>
<td>application</td>
<td>statements concerning further applications of the KEPTool and their benefits</td>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td>user interface</td>
<td>statements concerning the user interface of the KEPTool</td>
<td>3.3</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table 4.11: Deductive codes derived from the research design.
This coding scheme allowed for a general structuring of the recorded material. But, as suggested by Mayring (2014, p. 104), a combination of deductive and inductive procedures can be used, if the material should be reduced per theme. For an example he gives a study with an interview and interview agenda, which fixes the themes to be analysed in advance, i.e., exactly the situation in this thesis. Therefore he suggested, to first deductively code the material. In the second step, the material is coded per coding category, where the codes are derived inductively. This method was employed in this thesis and was necessary for the codes proposal, factor, and weight to further structure the material. For the first code proposal, three major strands could be derived and the code proposal was structured again with three inductively defined code categories: general remarks, individual remarks, and contrast. The general remarks capture all statements concerned with the overall proposal. The individual remarks target all statements which are concerned with parts of the proposal. Finally, the contrast captures statements which compare the proposal based on the collaborative rating to the proposal based on the experts’ individual rating. All statements in the proposal category could be assigned to one of these sub-codes. This helped to further structure the material and is reflected in Section 5.1.

Also, for the code category factor and weight sub-codes where assigned inductively. The codes were benefit, effort, and additionally, benefit vs. effort for weights. They describe, whether a statement concerning a factor or a weight is concerned with a benefit, an effort, or the contrast between those. Again, these helped to further structure the material and is reflected in Section 5.2 and Section 5.3.

Throughout the deductive coding using the codes given in Table 4.11 inductive codes were assigned in parallel (Mayring, 2014, pp. 106). The inductive codes allow to uncover important local factors (Miles et al., 2013, p. 81). For this, In Vivo coding was employed, which is especially suitable for beginners in coding (Miles et al., 2013, p. 74). As suggested by Miles et al. (2013, p. 74), the In Vivo codes are distinguished by quotation marks. The In Vivo codes were used to identify text passages, which could not be assigned to existing codes at first sight. Therefore the use of In Vivo codes proved easy to handle.

In the first analysis, only the In Vivo codes were assigned to text passages without further interpretation. Afterwards the codes were reviewed by the author and grouped to different categories. Thereby the In Vivo codes, which are given in the following, could be grouped in four different categories.

The first category is concerned with the experts’ issues to remember the knowledge elements from the Layers Theory Camp in detail, and was triggered by the following
These statements concerned the knowledge elements of the Layers Theory Camp, and reflect the problems the evaluators had to remember some of them. This was mainly triggered by the investigation of the proposal and will thus be discussed in Section 5.1.

A further category concerns the relationships in the KEPM and is reflected by the following codes:

- “trade-off”, “take out of calculation”, “false-positive”, “false-positive UI”

As these codes concern mainly the relationships in the KEPM, the corresponding statements will be discussed in Section 5.2.

Some statements were referring to developments in the LL project and related these developments to the KEPM. They were identified by the following codes:

- “Requirements Bazaar”, “for Thor-Arne and Gilbert’s work”

As this is related to application scenarios for the KEPTool, the statements will be discussed in Section 5.6.

Finally, the last set of inductive codes is concerned with the political implications of the KEPTool.

- “A defending M, me defending . . .”, “can’t be rated this way”, “straight forward”

These statements were also triggered by the investigation of the proposal and will therefore be discussed in Section 5.1.

For summarising and reducing the interviews, Mayring (2014, pp. 35) suggests five strategies: leaving out, generalisation, construction, integration, and selection. Because the experts mostly gave concise and structured answers, and the amount of interviews is small, mainly the selection strategy, accompanied by the leaving out strategy, was employed. That is, a central proposition was chosen from the text, because its content is important (Mayring, 2014, p. 36).
4.7 Summary

The case to apply the KEPTool is the Layers Theory Camp, a part of the LL project. In course of the Layers Theory Camp many knowledge elements were created. These knowledge elements were collected from the Layers Theory Camp wiki page. The topics of the knowledge elements could then be derived from the section headings in the wiki page and the types from the data formats. To reduce the rating effort, five adaptation criteria were selected and the distinction between manual and automatic preparation was dropped. Ratings for the benefits in the KEP Model were gathered via a self-administered on-line questionnaire among the members of the LL project. These ratings were thus determined collaboratively. For the rating of effort, to save rating effort, expert interviews were conducted. Finally, with all the data sets and ratings collected a proposal for the Layers Theory Camp could be computed by the KEPTool. This proposal is available in Appendix A.6, Table A.11 and serves as input for the consecutive evaluation.

For the evaluation structured interviews with experts from the Layers Theory Camp were conducted. The interviews were divided to evaluate three parts: the factors and weights in the KEP Model, the proposal, and the future of the KEPTool. The experts were sampled through the on-line questionnaire. The interviews were analysed with a qualitative content analysis after Mayring (2014). The analysis encompassed two parallel steps: deductive coding based on codes from the research design and inductive In Vino codes to incorporated notions brought up by the experts in the interview.

This chapter describes the ground work and basis for the next Chapter 5—the results of this thesis.
5 Results and Discussion

In this chapter the results of the interviews conducted as described in Chapter 4 are presented and discussed. First Section 5.1 is concerned with the evaluation of the output—the proposal computed by the KEPTool. The next two Sections 5.2 and 5.3 focus on the factors and the weights in the KEP Model. The next Section 5.4 investigates the rating procedure for the benefits in the KEP Model. Section 5.5 concentrates on the requirements for the user interface of the KEPTool, and Section 5.6 identifies further application scenarios. Finally, the chapter concludes in Section 5.7.

For Sections 5.1 to 5.6, first the results are presented and in a second step analysed and interpreted. Before the first section begins, some conventions are introduced. The experts are identified by Ex1 to Ex7. For verbatim quotes the following distinction is employed: “exact words said”. To repair sentence structures, sometimes words are introduced in brackets, e.g., “that was what [she] say[s]”. When grammatical errors in verbatim quotes do not obfuscate the meaning, the original wording is kept. Finally, if parts of the quote are left out, e.g., repetitions, this is indicated by “[..]”, e.g., “something [...] missing”. Finally, the interview with Ex1 was held in German. The translation to English is indicated by “[transl.]” and the original quote is given in a footnote.

5.1 Proposal of the KEPTool

In this section, the evaluation of the output, i.e., the proposal computed by the KEPTool for the Layers Theory Camp, which can be found in Appendix A.6, Table A.11, is presented. This section aims at sub-objective 1, the evaluation of the proposal the KEPTool computed for the Layers Theory Camp, in Chapter 1.

Four experts see the proposal as a good way to provide a summary, an overview, and a starting point. Ex1 states, that it “looks quite great as an overview [transl.1]”, because “we would have a ranking of what we should do [transl.2]”, if one “believes

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1 “sieht als Übersicht ja ganz Klasse aus”.
2 “Rangordnung hätten, was wir tun müssten”.

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the underlying aspects [transl.\(^3\)]”. Similarly, Ex5 notes, that the proposal can be “very useful internally for [...] the Learning Layers researchers” to understand how to “categorise this knowledge elements”. Ex2 finds that the proposal is “a really nice way of starting [...] to break it down”. Ex7 calls the proposal “very helpful for giving hints to the people who have to adapt the elements” and the Layers Consortium as it provides “a starting point from where on they can have a good idea how to really improve a knowledge element to make it useful for later purposes”.

Three experts voice a different opinion of the proposal. Ex3 observes that “everything fits to almost everything”. He is surprised, that “there is not consistency”, because as he notes “‘Complexity Theory’ has only two adaptation criteria whereas ‘Absorptive Capacity’ has four”, and they are “all wiki pages, they all describe some theories”. As he sees it, the proposal “basically [...] says you have proposed that ‘ATLAS Theory’ goes with device requirements] and [...] also goes with the presentation”, and then for language, he does not care “whether it is in Chinese or whatever”, which he finds “is not really the case”. Ex3 finds, contrary to the experts before, that “it cannot be used as a guide”, as “it allows spurious proposals to be in here”. Also, Ex4 does not “really see what the value [of the proposal] is”. He has “got some caveats [...] the fact that [it is] not mentioning a key theory, Vygotsky”. He finds, that the proposal is missing “the core debate from [his] work package 2 perspective, which is a bit of a shame”. He describes the exemplary evolution of some theories in work package 2 and concludes that “that’s what happened in reality. That’s the reality. And that’s what [their] report says. And that what’s the debates have been about, but what this, this doesn’t show reality, this tool” which he is “sorry to say”. Ex6 states, that for her the proposal “doesn’t really tell anything”. She does not see the proposal as valuable for disseminating the Layers Theory Camp results, “because it depends where you disseminate and what is the purpose of the disseminations. So some parts of it might be okay, some parts not”.

This summarises the statements the experts gave towards the proposal in general. Next some particular issues, which arose during the discussion of the proposal are presented. Three experts note, and are confused and surprised, that some knowledge elements got different adaptation criteria assigned. Ex2 says that she is surprised, that “[‘Absorptive Capacity’] has got so many different adaptation criterion”. Similarly, Ex6 is “not sure why some of them are [mentioned] so many times”. As described before, for Ex3 “it doesn’t make sense that ‘Complexity Theory’ has only two adaptation criteria whereas ‘Absorptive Capacity’ has four”. He does not see

\(^3\)”wenn man dem dahinter Stehenden glaubt”.
the reason for this, as “they all [are] wiki pages, they all describe some theories”.

Two experts, Ex2 and Ex6, and an anonymous survey comment remark that they find knowledge elements missing or superfluous. Ex2 says that “by the way, there is no mention of work package 2, which is a bit of a shame, given that we are a major player [...] in the project”. He continues that they “have Vygotsky and theories. That is an out and out. It is one of the few theories of learning that is used in the project”. Furthermore, he is surprised that “a lot of these things aren’t theories”. Ex6 notes about a particular knowledge element that she “still find[s] funny that the ‘Co-Design’ is there because it is not really related to the Theory Camp at all. It’s an accident to be in the [wiki page of the Layers Theory Camp] at all”. She also “first of all [...] noticed that there was nothing that was created by work package 4”, and that the “knowledge elements weren’t full”. When explained that the knowledge elements were assigned topics based on the section headings on the wiki page, Ex6 remarks “there are many section headings and many versions of it”, and so for her “it didn’t come clear which they were indicating to”. Further, a survey comment stated that “it missed all WP4 theory contributions”, whereas two examples are given by the statement with corresponding links in the comment.

Furthermore, some individual aspects of the proposal were picked up by some experts. Ex2 was surprised, and “would have had thought that language would be significant too”, because “really nearly everybody in Layers is multilingual, apart from us Brits, which is so embarrassing”. Ex4 investigated the knowledge element ‘Connectionism’, which is “quite a complex idea by Simons and Stephen Downes”. He noted “presenting it on a wiki page, [he is] not sure”. He mentions “a video of talking Stephen Downs”, which he finds “a quite good way [...] he explains it very well”. Ex7 reasoned about the wiki page for ‘Network Theory’ because he authored it. He “would fully agree to” the presented adaptation criterion presentation preference and reasons that “previous knowledge [...] is really not that important, because when you read a wiki page you can clearly open [...] another browser tab and read for this background knowledge”. Also, he finds “language is not that important for this wiki page here. Because, in my opinion, you can read it a couple of times”, and so “you have time to [...] somehow absorb it”. He concludes that “presentation preference with colours you know highlighting the most important things is really the most important thing that you need here”. What confuses Ex7 then, is that for “for example the wiki page ‘Absorptive Capacity’ here language is the adaptation criterion”. Similar to what Ex3 criticises about the wiki pages before, he “would have more expected that according to the type of knowledge elements the proposal would
be given”.

To counteract the problem that the experts are presented with a proposal, where
the ratings for the benefits differ substantially from the collaborative rating, for
each expert a proposal based on his and her ratings, taken from the survey, was
computed.

Ex1 finds that his individual and the collaborative proposal “seem to be relatively
close to each other [transl.4]” that there are “relatively small differences and appar-
ently [he has] seen that similar to others [transl.5]”. He finds this “high agreement
for the first five places remarkable [transl.6]” and concludes from this “that in this
respect [he] would have to say that the KEPTool seems to be working well [transl.7]”.
Finally, Ex1 thinks it interesting “what have the others seen how, where does it fit,
where does it not fit, and at least a pursuit of the first 5,6,7 positions [he] can imag-
ine [transl.8]”. Ex2 thinks “they are both valuable”. She “can’t really say that one is
better or worse than another” and thinks that they “both have value”. In contrast,
Ex3 is “struggling to see how [he] would recommend these and not make up a fuss
about Vygotsky not being in there and the social [...] construction of knowledge”. He
is not “quite sure how we got here”. In particular, he notes one knowledge element
that was included in his individual proposal and says that he “can’t remember what
‘Transcriptivity Theory’ is”. Ex5 thinks that she “agree[...] with the result” for
her individual rating. She was “happy doing the collaborative rating” and finds that
it “it is important [...] for the project to collect this kind of data”. She states that
“the collection of ratings and opinions [...] of the Learning Layers team [is] a good
way to collect this information”. So she thinks that the “collaborative is more im-
portant because this collects the [...] rating from everybody” and thus “in terms of
the project”, she thinks, “that is more important the collaborative one”. Ex6 finds it
“funny that it is so similar”. She cannot really say which proposal is more valuable
because “everyone who participated they have their own insight knowledge, it has
been put there”. So she concludes that “each one of them are valid in somehow
and the collaborative rating, “evens out [...] parts of it”.

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4 “scheint ja relativ nah beieinander zu liegen”.
5 “relativ geringe Unterschiede, also offensichtlich hab ich das ähnlich gesehen wie andere”.
6 “erstaunlich finde ich eigentlich schon, diese hohe Übereinstimmung zumindest auf diesen ersten fünf Plätzen”.
7 “Insofern müsste ich jetzt natürlich individuell sagen, also das KEPTool scheint gut zu funktionierenden.”.
8 “was haben die anderen wie gesehen, wie hab ich das jetz gesehen, wo passt’s zusammen, wo passt’s nicht zusammen und zumindest eine Beschäftigung mit den ersten 5,6,7 Plätzen kann ich mir schon vorstellen.”.
That collaboration also harbours some challenges can be seen by the following statements. Ex4 is a “bit confused to how [the selection of knowledge elements] would work”. He says, that “in reality, you have got people like A. defending Maturing, [him] defending Social Machines and hyper-social learning and networks, R. defending Absorption and the T. [...] defending Distributed Cognition, and that’s [...] to mention a few”. Ex6 “frankly think[s] that these kind of things cannot be rated this way” because there are “so many aspects of selecting certain elements out of others”. She is “not sure what is the English word for it but, ehm, ehm, it’s not expectations, but ... and it’s not really power relations, but it’s something that you are sort of supposed to show. So, so, sometimes that overruns all the other things”. She thinks, that the KEPTool could be applied for “something that is more straight forward” and where “purpose is not changing that much and there is not so much of this, let’s say, social rules on the play”.

A problem Ex1 brings up is the time span of roughly half a year between the Layers Theory Camp and the interview and the survey. He notes that he “does not immediately know what was discussed in Theory Camp Video 2 [transl.9]”. He repeats that to really understand what “Video 2,3,4 [were about .. he] would have to watch them [transl.10]”. He finds it difficult to “remember spontaneously what was presented about ‘Absorptive Capacity’, how the things were standing there [transl.11]”. He is “missing, so to say, a connection to remember more clearly [transl.12]”. Similarly, Ex2 remarks at the beginning of the interview “it’s been a little while since [she] was at the Theory Camp”, so she “may need [a little] prompt” to “remember some of it”. Also, Ex4 does not know what is in “the video 2, so [he] can’t comment”.

Ex7 describes that he is “not so much into the different elements as well as the adaptation criteria so that [he] can say that this specific output [...] would improve this in a certain way”.

After the presentation of the experts’ opinions on the proposal, now the opinions will be discussed, interpreted, and guidelines for improvement will be derived in the following. Four experts perceive the proposal overall as helpful to provide a summary, an overview, and a starting point. These experts welcome the proposal in general. From this, one may conclude that the KEPTool solves a problem that is relevant and interesting to these experts.

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9 “weiß jetzt natürlich nicht spontan, was im [...] Theory Camp Video 2, was da Thema war”.
10 “was sagt das Video 2, 3, 4. [aus..] dazu müsste ich mir jetzt die Videos anschauen”.
11 “zum Beispiel mich spontan zu erinnern, was wir da über ‘Absorptive Capacity’ hatten, wie der Stand der Dinge war, das finde ich jetzt nicht ganz einfach”.
12 “da fehlt mir sozusagen noch eine Brücke um mich genauer zu erinnern”.

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However, three experts were not satisfied with the proposal. Ex3 notes, that it lacks consistency, based on the fact that different adaptation criteria were assigned to one knowledge element of a certain type, but not the another knowledge element of the same type. Also, Ex7 expects the assignment to be based on the type of a knowledge element. Two further experts are surprised by assignment of multiple adaptation criteria to one knowledge element. The assignment of more than one adaptation criterion to a single knowledge element is possible in the current formulation of the KEP Model. This assignment is not based solely on the type, as assumed by Ex1, nor by the combination from type and the fact that they are all theories, as expected by Ex3. However, clearly some confusion arose from the multiple assignments. It may be worth investigating, whether the experts do not agree with the assignment of multiple adaptation criteria in general, i.e., whether they expect only one adaptation criterion to be assigned per knowledge element. This could be incorporated with an additional constraint in the KEP Model, but it is currently unclear, if this expected or wished for. However, it seems necessary, that the mechanics behind the KEP Model are described to the users to the extent, that they understand why the assignment of multiple adaptation criteria to one knowledge element occurs.

The second expert dissatisfied with the proposal, Ex4, based this on the fact that from his perspective a key theory was missing. The issue with missing knowledge elements arose again for Ex6 and one survey comment. First of all, it has to be mentioned at this point, that all knowledge elements accessible from the Layers wiki page have been included for consideration, as described in Section 4.2. However, the knowledge elements that were perceived as missing by the experts were not included in the proposal or not recognised because of the abstraction of knowledge elements to their respective topics and types. When Ex6 was explained that this may be the reason, she answers that the section headings, where the topics were derived from, changed several times.

Interestingly also a superfluous knowledge element is noted by Ex6. From this, several conclusions may be drawn. The collection of knowledge elements for consideration is a sensitive task. It requires some insight into which knowledge elements may not be relevant in the given context but accidentally made it into the source, i.e., the Layers wiki page. Potentially also the reverse is relevant, i.e., knowledge elements which may be relevant but not found on the Layers wiki page. Furthermore, the assignment of topics has to be made clear and transparent to the users, and again requires some in-depth knowledge about the knowledge elements to avoid a
wrong assignment to topics. It remains to be investigated, how such an assignment can be derived in a clear, consistent, and transparent fashion. One expert, Ex6, finds that she is lacking information on the context of the proposal. Albeit only one experts criticises this, it hints towards a lack of description of the application context. Thus, again it may be investigated, how the context and purpose of the KEPTool can be made clearer to the users. One extension can be derived from the detailed investigation of the knowledge elements. Ex4 mentions for one knowledge element that he is not sure whether the content of this knowledge element can be adequately transported on a wiki page. He suggests a video, which is present. This gives rise to an interesting aspect, which is currently not supported by the KEPTool: Changing the type of a knowledge element, e.g., as a further adaptation criterion. It remains an open question, whether and how this can be incorporated in the KEPTool and whether this is interesting in other cases as well.

Finally, the difference between the collaborative and individual proposal remains to be investigated. Most experts perceive the collaborative rating as positive. They note that it incorporates everyone’s knowledge. Ex5 explicitly states that she was happy doing the collaborative rating and favours the proposal based on the collaborative ratings. Albeit the KEPTool is not explicitly designed for it, the collaborative rating seemed to be welcomed by the experts. Thus, a further interesting aspect of investigation is the facilitation of the collaborative rating procedure. The data collected by this collaborative rating is perceived as important by Ex5. One expert, Ex1 notes the possibility of comparison with others in the collaborative rating. Interestingly, Ex1 concludes from the fact that his individual proposal is close to the collaborative one, that the KEPTool seems to work. He does not further justify this conclusion, but it may be interesting to find out, where this idea comes from. The individual proposal was easier to scrutinise from an individual level. Ex4 was dissatisfied with his individual proposal because a key theory is missing and another knowledge element he did not even know was present.

Interestingly, two experts saw the KEPTool as potentially useful for integrating different perspectives in a project as will be discussed in Section 5.6. But two experts argue in a different direction. Ex4 states the different perspectives in a project and is not sure how this could work. Ex6 finds too many social rules at play. Ex2 and Ex4 also were the experts missing their contributions to the project in the recommendation. The statements by the experts highlight the political aspects involved in the introduction of a DSSs. Thus, for a further development and different application of the KEPTool, an important aspect is to involve and integrate all
stakeholders.

The time span between the Layers Theory Camp and the presented recommendation of the KEPTool was not ideal. Thus, for future application, it might be sensible to employ the KEPTool closer in time. Through this, it would be easier for the experts to recall the knowledge elements and allow a more in-depth analysis of the recommendation. To achieve this, one has to take the time required for the rating procedure into account.

To summarise, this section investigated the output of the KEPTool. As already suggested in Section 2.3, the evaluation of the output of a DSSs is difficult, but this section works towards the evaluation of the output. The main results, however, do not give insight in the specific proposal, but they showed interesting aspects towards further improvement. The key points of this section, showing directions towards further improvement of the proposal, can be found in Section 5.7.

5.2 Factors in the KEP Model

During the interview, the experts were presented with the factors which represent the benefits and efforts in the KEP Model, and asked, whether they could find further factors. This section first investigates the results for the factors representing a benefit and continues with the factors representing efforts. The section aims at sub-objective 2 in Chapter 1—the evaluation of the factors influencing benefits and efforts in the KEP Model.

For the two benefits, importance of topic or type and need of an adaptation criterion, one expert is in agreement with both factors—“I think that these [...] are okay” (Ex5). Ex3 “might come up with a third [factor], but on the top of [his] head, no”. Ex1 identified “something like [...] expected benefit for the user [transl.13]” as a further factor. He further argues as the LL projects aim to reach out to “companies [transl.14]” as potential users of the developed tools, i.e., also the KEPTool, and stated for them also a “business-management perspective [is] important [transl.15]”. He continues, that “in the end it is always about the financial profit, or, enhancement of product, which includes a better market position too [transl.16]”. Ex1 concludes that he “somehow misses that a bit [transl.17]”. Ex2 included the “employees” in

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13 “so was wie [...] expected benefit for the user”.
14 “Unternehmen”.
15 “eine betriebswirtschaftliche Betrachtung [ist] auch wichtig”.
16 “geht es zum Schluss immer um finanziellen Profit. Beziehungsweise Verbesserung der Produkte, was aber halt auch wieder auch eine bessere Marktposition beinhaltet.”.
17 “Das fehlt mir da irgendwie noch”.

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her reasoning about the factors of benefits. She thinks that the employees “are going to be to be really significant as well, [...] because that’s where we are trying to get the benefits out.” Ex4 answers the question about further benefits with “is gotta be theoretical validity”, as “we are talking about the Theory Camp”. Ex6 states that she would “put there one: Fittingness to the research and stakeholders”. Finally, Ex7 includes “maybe something like a date” in his reasoning. He brings in the “aspect of out-datedness of [knowledge] elements. You have version 1, version 2 [...] so you have actually the same artefact but you have [...] two different versions”.

The factors influencing the efforts—complexity of a topic or type, experience of an employee, tool support, expected quality, and reusability of preparation tasks—were presented to the experts. Again, Ex5 thinks, that she “also agree[s] with this factors”, and Ex3 did not find an additional factor “off the top of [his] head”. Ex1 thought of “ideal or typical [transl.18]” factors such as “topics concerning safety or security [transl.19]” or “environmental issues [transl.20]”. He relates them to the stakeholders of the LL project of construction and healthcare, where these topics are important. Ex2 wondered whether “the complexity is an issue because it might depend on where you are in an organisation”. She referred to the stakeholders in the construction sector of the LL project and reasons, that the “experiences [of the apprentices] would be very different, to [...] for example the Meisters”. She also thinks that the “tool support possibly needs to be nuanced and there maybe needs to be something that briefs about the amount of effort that has to go in and who it is aimed at”. Ex6 cannot think of another factor “at the moment”, but agrees with some of the factors—“reusability is always good, tool support is always good”—but notes that “expected quality is quite of vague”. Further, she observes that “experience of an employee [...] goes sort of a little bit in another direction [...] The other ones can be taken more abstractly, the experience is quite directly than calculable to the used person months for the work”.

After the statements from the experts concerning further potential factors for benefits and efforts have been presented, the results are interpreted and discussed in the following. Five experts identify further factors for benefits: Ex1 the “benefit for the user” and the “business-management perspective”, Ex2 the “employees”, Ex4 the “theoretical validity”, Ex6 the “fittingness to research and stakeholders”, and Ex7 the “date” and “versions” of knowledge elements. Theoretical validity and

18 “idealtypische”.
19 “Sicherheitsthemen”.
20 “umweltbezogene Themen”.

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fittingness to research and stakeholders directly relate to the context the **KEPTool** has been employed in—the Layers Theory Camp. This supports the statement of Thalmann (2012, p. 302) that the benefits are highly organisation specific. Although these two factors are directly related to the context of the Layers Theory Camp, a general conclusion may be drawn from them: the necessity of relating the factors for benefits to the application context.

The remainder of the mentioned factors aim at a more general level. The benefit for the user is not explicitly stated as a factor in the **KEP Model**, but may be incorporated as an aspect of the current factors—importance and need. Also, the employees are currently not explicitly mentioned on the benefit side of the **KEP Model**. They are incorporated for the efforts by their experience, but not for the benefits. This is a possible extension to the **KEP Model**: The introduction of a further factor on the benefit side depending on each individual employee involved in the preparation tasks. This could be, for example, an additional factor towards the direction of interest of employee e, or, education purposes of employee e. Albeit the **KEP Model** has a strong resemblance to the classical cost-benefit analysis, as a method to evaluate DSSs briefly presented in Section 2.4, the business-management aspect is currently not explicit. The aspect of date and versions might reflect a time dimension and the evolving of knowledge elements. The incorporation of time and evolution of a knowledge element may be an interesting step for investigation.

The factors importance and need allow a very broad interpretation. Thus, the factors identified by the experts can serve as aspects of the present factors of benefits. They could clarify aspects according to which a decision maker can rate the present factors. For example, when rating the need of an adaptation criterion, the need of the user for this adaptation criterion is rated. Or, to give another example, the business-management aspects of financial benefits of a preparation task is rated.

Compared to the experts’ contributions of the factors influencing benefits, the contributions concerning the factors of effort are far fewer. This may be because on the one hand the factors concerning efforts leave less room for interpretation. On the other hand, when comparing with the weights the experts assign to the individual factors, the situation is reverse, i.e., the reasoning of the weighing of the factors is much more detailed for the efforts than the benefits.

Still, two factors, which can influence the efforts have been identified by one expert: aspects of safety and security, and environmental aspects. These factors are interesting, as they are frequently overlooked, and can considerably influence the efforts. These two factors are currently not incorporated in the **KEP Model**, but
might be an interesting extension. For the factors complexity and tool support a relation to the employees was suggested by Ex2. Currently the factors depend on the topics and the types. The perspective of the employees is incorporated via the factor experience with topic, type, and adaptation criterion of each employee. To rate complexity and tool support also with respect to employee increases the rating effort for these factors. Whether this additional effort is justified, remains to be investigated. This is, of course, true for all additional factors and aspects. Finally, Ex6 suggested a method to directly calculate the experience of employees: by used person months. As already suggested in Section 4.4 the current approach to the rating of efforts is fairly ad-hoc and labour intensive. By using measurements as the suggested one, which can be determined automatically, the rating of efforts can be improved.

It remains to be said that the distinction between a factor, which should be integrate into the KEP Model, and an aspect to instantiate to a factor in a concrete application scenario is not clear cut. For example, the security and safety factors brought up by Ex1 could be lifted to be a factor in the KEP Model. On the other hand one could argue that security and safety considerations can be captured by the factor complexity of a preparation task. To give another example, the monetary benefits may be incorporated as a factor, but may also be used to determine the importance of a knowledge element. Whether the factors, which have been identified by the experts justify the integration in the KEP Model or whether they serve as guidance to the instantiation of the factors in future applications remains to be investigated.

Finally, this section concludes with an observation concerning the relationships amongst the factors. Ex3 detected some “problem with the tool”. He thinks, it needs some “barriers, where you can say that when you are below certain things [...] then you do not want to come up” in the recommendation. He reasons that in the recommendation “basically you are saying, well you don’t care about it, but it’s very cheap, so do it”. In his opinion, this does not work in cases where “benefits and the efforts are far away [...] from each other on the wrong sides”. He also thinks, that a potential change would be to enable the user to identify an “irrelevant requirement” and “take that out of the calculation”. For the presented recommendation he reasons that there is “all this noise and these device requirements”. He identified this as “false-positives”. He suggests, that this could also be incorporated in the user interface with “an indicator here that, that shows where there is an, a high probability that this proposal is a false-positive”.

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Ex3 asks for the possibility to explicitly exclude irrelevant topics, types, or adaptation criteria. Currently, the **KEP Model** does not support the exclusion of a topics, types, or adaptation criteria when they are perceived as not relevant to the decision maker. It is possible to exclude a combination of type and adaptation criterion by the feasibility constraint, but no constraint directly allows to exclude a topic that is perceived as not important or an adaptation criterion that is not needed. It remains to be investigated, whether the possibility of excluding topics, types, and adaptation criteria, or combinations of them, should be integrated in the **KEP Model**.

A summary of this section can be found in the final Section 5.7 of this chapter.

### 5.3 Weights in the KEP Model

In the interview the experts were asked, whether they perceive some factors of benefits and efforts more important than others. The objective of this question was to arrive at some weights and reasons for weighing. First, the weights assigned to the benefits are presented and discussed, followed by the weights of the efforts. This section aims at sub-objective 3 in Chapter 1—the evaluation of the weights.

For the benefits, four experts perceived the importance and the need as equally important—Ex1, Ex3, Ex6, and Ex7. Ex1 thinks, that “both are equally important, if one of them is not present, then it wouldn’t work, would it? [transl.]”. Ex3 reasons that “both are important, I can’t have one without the other”. Two experts, Ex2 and Ex4 see the importance of topic as more important. Ex2 states that for her “it is definitely [...] the importance of the topic”. Also, Ex5 states, that for her “the importance of topic or type. It will be more important than the other”.

For the weights concerning the benefits, the weights were set by the experts with relatively little reasoning provided. The situation is quite different for weights concerning the effort. For weighing the efforts, the answers given by the experts were less straight forward. Two experts, Ex3 and Ex5 reasoned about the weights of the efforts by dividing them. Ex3 reasoned with “let’s say we have [...] things that are more important and things that are less important”. Then he judged tool support as “kind of on the less important side, probably then neutral”, and “complexity is on the important side. Experience is definitely on the important side. Expected quality, eh, is on the important side”. For reusability, he reasoned that it depends: “Yeah, of course, if I don’t do it again than I don’t care. But if I have to do it 5000 times than

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21 "Ich denke, die sind beide gleich wichtig, wenn da einer nicht richtig ist, dann funktioniert’s auch nicht gut, ne?". 
I do care, so probably you don't have to do this too often. So I would say it's on the less important side. Similarly, Ex7 makes a difference “between influencing effort that drive the effort and the efforts” and based on this he “would say the drivers are more important maybe”. He sees the “expected quality as the main driver of effort”, and the “reusability [...] at the same level like expected quality somehow”.

Finally, the experts were asked whether they consider benefits or efforts as more important. Three experts, Ex1, Ex2, and Ex4 consider benefits more important. Contrary, Ex5 thinks that “maybe [...] the effort” is more important. She bases this on her observation, that for her “it is important, the experience”. So she thinks “probably [...] the effort is more important than the benefits”. Ex3 does not perceive one as more important than the other, because he is interested in “the trade-off”. He is “interested in what is the cost benefit. Together”. For Ex6, whether one is more important depends on “what is the task and what is the goal with it”. For this case, she reasons, “when everything is done, it was the benefits. With some other cases it might be the efforts”.

After the presentation of the statements and reasoning provided by the experts, now these will be interpreted. Albeit some trends can be identified, e.g., for the factors concerning the benefits most experts rated the factor importance of topic and type as equally important to need for adaptation criterion, the sample is too small to derive any significant trends. Still it is worth noticing that for all factors weights were assigned, although not always the same. Thus, the conclusion may be drawn, that the experts welcome the opportunity to set different weights on factors. Especially for the weighing of efforts, the reasoning by the experts was quite detailed. The setting of weights in the model is a sensitive problem, as already demonstrated by Thalmann (2012). They have to be set carefully to match the experts’ expected outcome. For future application of the KEP Model the setting of the weights seems an open issue. They should be iteratively tested, until they match the users expectations.

5.4 Rating Procedure

In the interview, the experts were asked about their reasoning behind the rating of the benefits they performed in the survey. Here, the results will be presented and discussed, including comments, which were given in the survey. This section aims at sub-objective 4, the evaluation of the rating procedure of the factors influencing the benefits, from Chapter 1.
Ex1 states his rating was “to be honest, a spontaneous assessment [transl.22]”. But he emphasises that it was “mostly based on the work with the stakeholders [transl.23]” in the LL project, that he assessed what “could fit the stakeholders [transl.24]”. Ex2 thought about “how important it was to pull together the different types of theories that people had put up for the, eh, the Theory Camp” as also suggested by “the year one reviewer comments”. Therefore she moved “away from the kind of theory that [she] presented at the Camp and [...] was looking at the bigger picture”. Based on this bigger picture she looked at “which of these different adaptations and so on would be most important in kind of trying to move [the integration of theories] forward”. Ex3 states, that he “just rated it by what it is”. He rated, “whether the topic is important or not. And whether a certain adaptation works or not. For [him]”. Ex5 based the ratings on her “personal experience with [...] the knowledge elements”. She states, that if she “ha/s] used this elements before more than the others, [she] include them a better, eh, rating than the other”. For Ex6 “many of the claims were [...] not clear to [her] what they meant” and she “could have interpreted them in many ways”. For her it was not clear whether she should rate for where it should be presented, or how it should be presented or what was the adaptation for. So to answer them she first had to try to “select what might you be meaning in, with the claim and then according to that place some kind of rating out of it”. This fits well with two survey comments. The first anonymous statement declared that “It is not clear to me who the intended audience is and what is the purpose of sharing this” and continuing by “Without knowing that it is hard to answer these questions as the answer depends very much on the audience”. The second statement in the survey similarly read: “I do not understand the above formulations, what do need to be answered in here”. A detailed reasoning for the rating procedure concerning the type video and the adaptation criterion prior knowledge was given by Ex7. He states, “that certain types, for example, [are] of different importance, because they have different level of richness”. He continues that he “would consider it more important to have a video than just a picture, because a video [...] is richer. You have voice, [...] you have the visual aspect and a picture just gives you the visual channel”. Further, Ex7 notes for adaptation criteria, that “to come up with [...] an improved knowledge element [...] basically depends on, of course, various factors, but my reasoning behind was that there are some factors that are heavier than others”. He noted for example previous

22 “eigentlich ehrlich gesagt so ein spontanes Einschätzen”.
23 “vor dem Hintergrund der, vor allem der Arbeit mit den Stakeholdern”.
24 “was könnte passen, zu unseren Stakeholdern”.
knowledge, by arguing “you need to have the context in order to understand actually the element as well as the improved element”.

After the presentation of the statements by the experts, the statements will be interpreted. The experts gave various different ways they reasoned about the ratings. To summarise, Ex1 assessed his rating spontaneously in hindsight of the stakeholders. Ex2 tried to look at the bigger picture of the LL project, whereas Ex3 rated from his individual perspective. Ex5 based her ratings on her experience with the different knowledge elements. Ex6 had some difficulties discerning the meaning of the ratings, as two survey comments suggest as well. Finally, Ex7 gave some insight into how he reasoned in two specific instances.

The experts employed a broad range of approaches to the rating, from the individual experience to the overall picture. From this one may derive the importance of guiding the decision maker—especially if the ratings are performed collaboratively. One possibility, as suggested already in Section 5.2 may be to clarify the factors importance and need, which leave open a relatively large room for interpretation. Therefore, e.g., aspects to which the factor should be rated could be clarified. Additionally, as can be seen by the various ways employed to arrive at ratings, it may help the decision makers to clarify from which perspective they should perform the rating, e.g., his or her individual perspective or a holistic view.

5.5 Graphical User Interface

The experts were asked about requirements for the graphical user interface for the KEPTool. Thereby four major requirements arose: a more detailed description, requirements on the language, inclusion of the associated rating, and layout suggestions. This section aims at sub-objective 5 in Chapter 1, the identification of requirements on the graphical user interface.

Two experts, Ex1 and Ex5, ask for more detailed descriptions. Ex1 notes, that he does not know “spontaneously, what was topic in the [...] Theory Camp Video 2 [transl.25]” and thus it would be “nice, if there were some terms there, such that he could spontaneously associate [transl.26]”. He notes the same for ‘Absorptive Capacity’, where he is not sure what “was really presented there [transl.27]” or for the adaptation criteria device requirements and presentation preference, where

25 “spontan, was im [...] Theory Camp Video 2, was da Thema war”.
26 “schön wär’s, wenn da jetzt ein paar Begriffe dabei wären, damit ich spontan assozieren kann”.
27 “was wurde wirklich bei ‘Absorptive Capacity’ da benannt”.

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“both obviously do not tell much in the table [transl.\textsuperscript{28}]”. He suggests, that it may be interesting for “subject areas [transl.\textsuperscript{29}]” to “symbolise them graphically somehow or some key words appear [transl.\textsuperscript{30}]”. Similarly Ex5 suggests a description “about the different elements that the \textit{KEPTool} is using”. She gives as examples “what do you mean about knowledge elements, what do you mean about adaptation criteria”. This, she reasons, would help the user because he or she “can go and read the description” which helps him or her to “understand better [...] the result obtained”. Also, Ex5 notes that each knowledge element in the table is referring to a certain element and it might be possible to “have the link between the knowledge element and the corresponding result”, which she would find “very useful”.

Language is mentioned by two experts, Ex2 and Ex5. Ex2 suggests “looking at different languages”. She reasons that it may be “worth considering” as “there isn’t so much text” and she thinks “it would look very nice if you could have it in different languages”, and explains that if something “is very difficult, it’s extra difficult if it is not in your original language, if it is not in your first language”. In the same manner, Ex6 states: “Only for me, I need a simple language to know what is meant”.

Two experts query for the associated ratings in the result—Ex3 and Ex7. Ex3 asks “what’s the link now between the benefits and knowledge element and the adaptation criterion? It’s very confusing”. He finds, that what “of course [would] be interesting here is the benefits”. Similarly, Ex7 expected “something like a benefit-effort ratio [...] some key measure”. Related to this is maybe a request by Ex5 about the “clarification about the order of the elements”, to understand “why some element appears in the first position and some element appears in the 37”. The ranking is also noticed by Ex1, who observes that “at the same time many of those ranked low are left out [transl.\textsuperscript{31}]”, because one thinks “what is ranked on position 30 is obviously unimportant [transl.\textsuperscript{32}]”.

Finally there were some general suggestions about the design of the user interface. Ex2 finds, that the presented table looks “a bit computer-sciency and clunky” and asks for a “nice design interface, so for the fronts and kind of pressing buttons, and it looking a bit more seamless”, and to make it “more visually appealing”. She also notes that the quality of the tool is “really, really important”, because if “quality is poor, it doesn’t matter how experienced an employee is. They’ll see that it is

\textsuperscript{28} “das sagt natürlich beides jetzt in der Tabelle wenig aus”.

\textsuperscript{29} “Themenfelder”.

\textsuperscript{30} “irgendwie grafisch noch mal symbolisiert werden oder noch mal Stichwörter auftauchen”.

\textsuperscript{31} “gleichzeitig fliegt natürlich vieles von dem, was unten gerated ist, raus”.

\textsuperscript{32} “was auf Platz 30 gelandet ist, ist offensichtlich unwichtig”.
poor quality, and they are not going [...] to bother to find out more about it”. Ex7 suggests “a drag and drop thing”, and to “make it visual”. He also suggests, as Ex1, “icons for [different knowledge elements], or at least for the types”, or “something like a tag”. Then the user can “drop it like into this box that you have here [on the presentation slide]”. And then you have “some calculations and then you see a pop-up where it says, okay, how, according to which adaptation criteria [...] for whom it should be prepared”. Ex3 suggests a “more aggregate views on the results”, and to “slice-and-dice results in a way”. He says, that the data “feels a bit raw”. He also suggested some “quality aggregators”, some kind “red-green-orange traffic light thing”, which would “give you an idea of whether the outcome of it is clear cut, or whether there is so much ambiguity in it that you can actually not really take a decision”.

After the presentation of the requirements the experts voice for the graphical user interface, now some interpretation and suggestion will be derived from that. Two experts ask for additional information concerning key measures in the recommendation. That is, they either would like the rated benefits or the benefit-effort ratio presented. This aspect may be interesting for the further design of the user interface. By the presentation in a table, a ranking was suggested, as was picked up by two experts. This is not necessarily the case, as the KEP Model recommends based on the capacity constraints and the recommendation might change significantly, when the capacity constraints change. That is, the presentation of the recommendation should not imply some ranking but rather support a holistic view. On a similar note Ex3 suggests the aggregation of the recommendation with the possible extension to a simple key measure system based on traffic lights. Two experts ask for some adaptation concerning the vocabulary and language used in the KEPTool. One expert asks for a translation to different languages. One expert suggests an explicit definition of the terminology used in the tool. Both suggestions could easily incorporated in a non-prototype implementation of the KEPTool. Two experts suggest to tag the knowledge elements, or their types, with keywords or graphic icons. This would of course raise the usability, but it remains to be investigated, how this can be incorporated in the KEPTool with reasonable resources.

5.6 Application Scenarios

After the presentation of the KEPTool and the investigation of the recommendation, the experts were asked whether they could identify further application scenarios for
the KEPTool. The results will be presented and discussed in the following. Finally, this section aims at the last sub-objective 6 in Chapter 1, the identification of further application scenarios.

Ex1 sees the KEPTool as an “interesting thing for one’s own reflection [transl.33].” When the KEPTool provides such a recommendation then it is “occasion or trigger to look again closely [transl.34]” and to investigate what the individual knowledge elements contained. Reflection, Ex1 states, is part of learning, and thus he can see an application of the KEPTool in working with apprentices, where it could provide “additional reflection, an additional reflection trigger [transl.35].” The apprentices could rate topics “that they have done in the last half year [transl.36].” Hereby, Ex1 notes, it is important to “avoid the effect, that what was topic in the last two weeks seems especially important and what was done two months or three months ago […] does not seem so important any more [transl.37].” Ex1 can see the KEPTool as “practically a new didactical tool, which certainly could give the trainer or teacher a good feedback, as well as the learner [transl.38].” For companies, Ex1 perceives the KEPTool as “rather difficult, but [he] would have to think about it [transl.39].” He reasons, that it would heavily depend on “how open the communication is [transl.40].” Still, for a project such as the LL project, with “groups with different backgrounds, with different perspectives [transl.41],” he perceives the KEPTool as “surely something that one could work with [transl.42].” Finally, Ex1 found, that he would like to “try [the tool] himself, when an opportunity arises [transl.43].”

Ex5 saw the potential in the KEPTool as “a good way to organise different knowledge elements”. She suggests that it might be useful to apply this model within the work packages in the LL project, with the “different members, and different partners, I mean from different universities etc.”, or also within a research team.

33 “spannende Geschichte für die eigene Reflektion”.
34 “natürlich ein Anlass noch mal genau zu schauen”.
35 “eine zusätzliche Reflektion, so einen zusätzlichen Reflektionsanlass”.
36 “deren Themen, was sie wichtig halten, jetzt zum Beispiel im letzten halben Jahr, was da so gemacht wurde, wenn die das raten würden”.
37 “den Effekt zu vermeiden, dass das was gerade in den letzten zwei Wochen thematisiert wurde erscheint besonders wichtig und das was vor zwei Monaten oder drei Monaten war […] nicht mehr so wichtig erscheint”.
38 “ein neues didaktisches Tool eigentlich, was natürlich sowohl dem Trainer oder Lehrer ein gutes Feedback gibt als auch dem Lernenden selber”.
39 “eher schwierig, aber da müsste ich noch einmal genauer darüber nachdenken”.
40 “wie offen findet die Kommunikation statt”.
41 “Gruppen, die aus unterschiedlichen Bezügen kommen, verschiedene Perspektiven haben”.
42 “schon was zu sein womit man arbeiten könnte”.
43 “mal selber ausprobieren, wenn es eine Gelegenheit gibt”.

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She finds that in “some way maybe it could be useful to apply this model in a work package [...] to discuss about different knowledge elements that are discussed only in this work package”. She can also imagine the application “with PhD students” in a “research methods class room”, to discuss the “elements that they have discussed and then they have to use this tool to [...] organise them”. Ex6 would see an application of the KEPTool in a “more straight forward [context]”, where “the purpose is not changing that much and there is not so much of this, let’s say, social rules on the play”. She thinks for “more concrete, ehm, issues and situations [...] it could work quite well”. She expects that the tool could make “some of the discussion faster, so, sort of could be used as a basis and then decide how well it will be followed or not”, especially when “a huge amount of people” is involved. As an example, Ex6 could think of a “quarter [where] inside there is this space that, that different apartments build inside, sharing”. For this shared space she explains that “they usually argue what kind of things should be there”. She finds this situation as “more concrete and there is sort of concrete restrictions how far you can go anyhow in modifying those”. This situation, she concludes, is not so “fluid, let’s say so”. Finally, Ex7 sees the potential to apply the KEPTool to “to improve knowledge management in a sense of that it helps to manage the different knowledge elements better in a way the people who have to work with them can make more use of it”. Thereby, it “could reduce communication efforts, because the elements are prepared in a better way and hence people don’t have to ask a [...] lot of times” or users would “loose not that much time because they have to scroll the whole text, because this text can be highlighted better and so on”. Finally, he states that the “presentation preference for a certain user [...] to be customised somehow, personalised to user”. He concludes that he can see the KEPTool in “in an organisational context it would improve knowledge management processes”.

After the summary of statements given by the experts, now an interpretation follows. Two experts see the potential to employ the KEPTool in teaching. Ex5 suggests it in a PhD students classroom where she sees the possibility to use it to organise different knowledge elements, they have learned. Ex1 is more detailed, where he sees the KEPTool as a didactical tool to work with apprentices. He finds it a tool for reflection and for feed-back. This application scenario may be an interesting further direction of the KEPTool. Thalmann (2012) developed it originally for the application within an organisation. The employment of the KEPTool in a teaching or learning situation is an aspect, which may be investigated further. For the learners it may provide an overview and starting point, as suggested earlier in Section 5.1.
Ex1 gives the rating of knowledge elements as a task to the learners, which seems an interesting method to reflect. However, it is unclear and remains to be investigated, what the purpose of the recommendation provided by the KEPTool could be then. The same experts also see the KEPTool in project work where it could help to bring together people with different perspectives and backgrounds. Potentially, this idea is strongly influenced by the current application of the KEPTool in this context, i.e., the application for the Layers Theory Camp. They see the potential to organise and discuss the knowledge elements. Especially Ex5 is quite positive about the collaborative rating to establish the benefits. The aim to employ the KEPTool in the context of a project is at odds with the observation of Ex6, who finds, that the KEPTool should be employed in a context with less ambiguity. To manage the ambiguity in a project with different perspectives, it might be worth investigating, how the collaborative rating can be better supported. Further, the KEPTool could move towards more flexibility, which allows more ad-hoc and what-if analysis. One challenge hereby is the one in mentioned in Chapter 3, NP-completeness of the problem, which makes a fast re-computation difficult. Ex6 finds that the KEPTool could be employed in a more concrete setting. She gives the example of deciding what could be installed in a shared space in a quarter. Interestingly, for her scenario she also assumes many people to be involved in the decision, but she finds this a more concrete setting with more concrete constraints. Conclusively, three experts find the collaborative aspect interesting, thus it may be interesting to further investigate how the KEPTool can support this. Finally, Ex7 sees the KEPTool employed for knowledge management to improve the knowledge elements. This most closely fits to the original idea and context the KEPTModel was developed for.

Relevant to the LL project is the connection some experts established to other tools in the project. Two, Ex3 and Ex4, established links to the Requirements Bazaar. Ex4 further highlighted the integration requirements with the Social Semantic Server. Moreover, Ex2 could see a connections to the work with clusters.

5.7 Summary

This summary lists potential areas for further investigation and improvement collected through the expert interviews. Throughout this chapter, the order in which the items appear in the tables does not express any ranking or prioritisation.

First, potential areas for further investigation and improvement of the KEPTModel are given. For the factors in the KEPTModel the suggestions shown in Table 5.1 have
been derived. It remains to be investigated which of the suggested factors could and should be integrated as factors in the KEP Model, and which of them can be seen as guidance for the instantiation of factors.

<table>
<thead>
<tr>
<th>SHORT DESCRIPTION</th>
<th>LONG DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 benefit factor depending on employee</td>
<td>Investigate the incorporation of a factor on the benefit side which depends on the employee performing the preparation task.</td>
</tr>
<tr>
<td>2 factor concerning time, date, or version</td>
<td>Investigate the incorporation of a factor concerning time, date and/or version.</td>
</tr>
<tr>
<td>3 factor concerning safety, security, or environmental aspects</td>
<td>Investigate the incorporation of a factor on the effort side concerning safety, security, and environmental issues.</td>
</tr>
<tr>
<td>4 investigate how factors can be instantiated</td>
<td>Investigate how the factors can be instantiated in a concrete application scenario, e.g., importance and need could be specified with fittingness to stakeholders, relevance to research and stakeholders, fittingness to theory.</td>
</tr>
<tr>
<td>5 (automatic) rating procedures</td>
<td>Investigate procedures to rate factors, if possible automatically.</td>
</tr>
</tbody>
</table>

Table 5.1: Suggestions concerning factors in the KEP Model.

A summary of the suggestions concerning the relationships in the KEP Model is shown in Table 5.2.

<table>
<thead>
<tr>
<th>SHORT DESCRIPTION</th>
<th>LONG DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Exclusion of topics, types, or adaptation criteria</td>
<td>Investigate, whether it is required to include the possibility to exclude topics, types, adaptation criteria or combinations thereof.</td>
</tr>
<tr>
<td>2 Technical evaluation</td>
<td>Perform technical evaluation on small, constructed test cases.</td>
</tr>
<tr>
<td>3 Change types of knowledge elements</td>
<td>Investigate, whether it is possible and required to change the type of a knowledge element.</td>
</tr>
<tr>
<td>4 Only one adaptation criterion</td>
<td>Investigate, whether at most one adaptation criterion should be assigned to each knowledge element.</td>
</tr>
</tbody>
</table>

Table 5.2: Suggestions concerning relationships in the KEP Model.

Next, some suggestions for the evolution of the KEPTool have been derived. Some suggestions for future applications and evaluation of the KEPTool are given in Table 5.3. For the user interface the suggestions listed in Table 5.4 have been given.
<table>
<thead>
<tr>
<th>SHORT DESCRIPTION</th>
<th>LONG DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Clear description</td>
<td>Provide a clear description of the application and aim.</td>
</tr>
<tr>
<td>2 Collaborative ratings</td>
<td>Explore the incorporation of collaborative ratings.</td>
</tr>
<tr>
<td>3 Assignment of topics</td>
<td>Investigate a transparent mechanism for assigning topics and types to the knowledge elements, such that for all involved experts the assignment is clear.</td>
</tr>
<tr>
<td>4 Assignment of types</td>
<td>Investigate a transparent mechanism for assigning topics and types to the knowledge elements, such that for all involved experts the assignment is clear.</td>
</tr>
<tr>
<td>4 Assignment of stakeholders</td>
<td>Assure the involvement and integration of all stakeholders and do not underestimate the political implications.</td>
</tr>
<tr>
<td>5 Guidance in rating</td>
<td>Investigate support and guidance to the decision maker for the rating of factors.</td>
</tr>
<tr>
<td>6 Setting of weights</td>
<td>In general the weights are welcomed by the experts, but perceived differently. Future work is the iterative setting of weights until they match the expectations.</td>
</tr>
<tr>
<td>7 Timely proposal</td>
<td>Reduce the time span until the proposal is presented for an in-depth investigation of the proposal.</td>
</tr>
</tbody>
</table>

Table 5.3: Suggestions for applications and evaluation of the KEPTool.

Different application scenarios for the KEPTool have been suggested, shown in Table 5.5.
<table>
<thead>
<tr>
<th>Short Description</th>
<th>Long Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Keywords or icons</td>
<td>Explore the possibility to equip the knowledge elements, and their topics or types, with links to the corresponding resource, explanatory keywords, and icons.</td>
</tr>
<tr>
<td>2 Different languages</td>
<td>Explore the support of different languages.</td>
</tr>
<tr>
<td>3 Terminology</td>
<td>Define the terminology used in the KEP Model, e.g., define “knowledge element” and “adaptation criterion”.</td>
</tr>
<tr>
<td>4 Aggregation</td>
<td>Explore the possibilities to aggregate the proposal.</td>
</tr>
<tr>
<td>5 Key measures</td>
<td>Explore the possibility to add key measures as e.g., benefit-effort ratio.</td>
</tr>
</tbody>
</table>

Table 5.4: Suggestions for the user interface of the KEPTool.

<table>
<thead>
<tr>
<th>Short Description</th>
<th>Long Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Didactical tool</td>
<td>The application of the KEPTool as a didactical tool, for example with apprentices or PhD students, for reflection and organisation.</td>
</tr>
<tr>
<td>2 Project work</td>
<td>The application of the KEPTool in the context of a project, working group, or research team.</td>
</tr>
<tr>
<td>3 Knowledge management</td>
<td>The application of the KEPTool for knowledge management in companies.</td>
</tr>
</tbody>
</table>

Table 5.5: Suggestions for different application scenarios of the KEPTool.
6 Conclusion

As promised in Chapter 2, the work in this thesis will be concluded by reviewing it with respect to the seven guidelines for DS research developed by Hevner et al. (2004).

- **Guideline 1: Design as an Artefact.**

The first guideline of Hevner et al. (2004, p. 75) states that DS research must produce a viable artefact which can be implemented. The starting point of this work, the KEP Model, can be conceived as a DS artefact. This artefact has been implemented in course of this thesis. Therefore, the KEP Model has been translated to the declarative programming language GMPL, a subset of AMPL, to produce the KEPTool. Several LP solvers accept AMPL as input language, thus the implementation does not depend on a single solver. For exchanging data CSV files are employed. These decisions allow for a low overhead and easy integration. With the KEPTool this thesis produced a further DS artefact. This artefact was applied in a real world context—the Layers Theory Camp. This enabled the evaluation of the KEP Model and the KEPTool as stipulated by guideline 3.

- **Guideline 2: Problem Relevance**

The second guideline demands that DS research provides a solution to an important problem (Hevner et al., 2004, p. 84). The importance of the underlying problem of the KEP Model, i.e., the selection of knowledge elements for adaptation, was demonstrated by Thalmann (2012) and has been confirmed by the experts interviewed in course of this thesis. The focus of this work was the problems the KEP Model faces for future development. As a DS artefact evaluation is vital as reflected by the following guideline 3. For the KEP Model and the KEPTool as a DSS the early evaluation is important for evolution. Therefore the integration of users is crucial to shape the development in the desired direction.

- **Guideline 3: Design Evaluation**
Hevner et al. (2004, p. 85) state that the “utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods”. The evaluation of the KEP Model was the main motivation of this thesis. It is, next to the implementation and the application, also its main contribution, as reflected in the research objective. The evaluation was achieved by applying the KEP Model and the KEPTool in the context of the Layers Theory Camp and a consecutive evaluation through interviews with experts as potential users of the DSS.

This evaluation has 6 sub-objectives which will be discussed in the following. The first sub-objective aimed at the evaluation of the proposal the KEPTool computed for the Layers Theory Camp. The experts gave some suggestions towards the improvement and modification of the model and the tool based on the presented proposal. Their statements showed the importance of integrating different stakeholders. Suggested and derived points for investigation are the possibility to exclude topics, types or adaptation criteria, which are rated below a threshold, the change of types of knowledge elements, and the assignment of at most adaptation criterion each knowledge element. Further the need of a transparent selection and assignment of topics and types to knowledge elements was highlighted. The second sub-objective aimed at the evaluation of factors influencing the benefits and efforts. Overall the interviewed experts agreed with the present factors in the KEP Model. It remains to be investigated whether the additionally suggested factors should and could be integrated as factors in the KEP Model. The suggestions can also support the instantiation of the factors in future application scenarios. For the benefit side the incorporation of a factor depending on employees, and a factor concerning time, date, or versions was suggested. For the effort factors dealing with safety, security, or environmental issues were brought up. The third sub-objective aimed at the evaluation of the weights balancing the factors in the KEP Model. Although some trends could be identified, the sample size was too small for any significant result. Still, all experts welcomed the possibility to assign different weights to the factors. The fourth sub-objective aimed at the evaluation of the rating procedure. The experts employed different strategies to perform the ratings. This calls for a deeper investigation on how to guide the rating procedure, especially in a collaborative setting. Some of the ratings may be derived, even automatically, from existing data, as suggested e.g., for the experience of employee by one expert. The fifth sub-objective aimed at the identification of requirements for the graphical user interface. The experts suggested to equip the knowledge elements with keywords or icons, the integration of different languages, and the detailed description of terminology. They
also suggested aggregation and the display of key measures. The final sub-objective 6 aimed at the identification of further application scenarios. Here the experts suggested the application of the KEPTool as a didactic tool, to support collaboration in project work, and for knowledge management.

- **Guideline 4: Research Contribution**

  The fourth guideline is concerned with research contributions, which after Hevner et al. (2004, p. 87) can be a new artefact, foundations, or new and innovative methodologies. As described in guideline 1 a new artefact, the KEPTool, has been produced in course of this thesis. This artefact, and the KEP Model, have been evaluated as described in guideline 3. This encompassed the collection of suitable input data and ratings. Based on this a method to evaluate the artefact has been developed. This evaluation lays the groundwork for further developments of the KEP Model and the KEPTool. Thus, the major contributions of this thesis are the implementation of the KEPTool, the application of the KEPTool, which encompasses the collection of data and ratings, and the method and results of the formative evaluation of the KEP Model and the KEPTool.

- **Guideline 5: Research Rigour**

  In their fifth guideline, Hevner et al. (2004, p. 83) stress the importance of applying rigorous methods in the construction and evaluation of DS research. Chapter 2 lays the foundation for this thesis. It explores the principles of DS research, the seven guidelines which are guiding this conclusion, the cycle model, and the DS research methodology process model. As the KEPTool is a DSS, literature concerning DSSs is reviewed in Section 2.3 and methods for evaluating DSSs are explored in Section 2.4. Based on this groundwork, the application and evaluation are conducted. The data collection and the collection of ratings through an on-line survey and expert interviews is described in detail in Chapter 4, as are the conducted expert interviews. The data analysis follows the recommendations of Mayring (2014).

  At this point, limitations of this work shall be named. As a case study, due to the limited sample size, and by the focus on the evaluation of a specific artefact, the results are not easily generalisable or transferable to a different context. However, this was not the focus of this work. The distinction of manual or automatic preparation of knowledge elements is not considered in this thesis and left open for further work. Next, the collection of the data set and ratings has some limitations. For one, the assignment of topics and types to knowledge elements was not evaluated.
As input for the KEPTool, only ratings for importance and need, i.e., the benefits, are determined collaboratively. The effort is determined by an expert rating, as this reduces the rating effort for the participants of the questionnaire significantly. These ratings are subject to subjectivity of the experts and participants in the survey.

- **Guideline 6: Design as a Search Process**

With this guideline Hevner et al. (2004, p. 88) suggest that DS research is an iterative process to discover an effective solution and a search for improvement. Similarly, the evolution of a DSS is iterative as described in detail in Section 2.3. The main objective of this thesis is to show directions for enhancement of the KEP Model and the KEPTool through the application in a real world context, the Layers Theory Camp, and a formative evaluation. This work is the continuation of the efforts from the initial presentation and demonstration of the KEP Model by Thalmann (2012). By definition, formative evaluation seeks potential improvements.

This guideline was also honoured in Section 3.1 for the implementation of the KEP Model. Several design options were investigated and evaluated in this section. The selection of the GLPK solver and the modelling language GMPL was based on this investigation of different solving paradigms and available solvers. Also, for the evaluation method, possible options were investigated in Section 2.4.

By no means, however, is the search process completed with this thesis. On the contrary, the objective of this thesis was the search for potential areas of improvements. These are described in detail in Chapter 5, and summarised in Section 5.7. An area, which has only be rudimentary been explored, is the automated rating of knowledge elements based on meta data. This has been briefly investigated in Section 4.4 and would be an interesting direction for further investigation. In the same section a further area for investigations are given. So far, the automatic and manual preparation of knowledge elements has not been subject to evaluation and would prove to be an interesting further point.

- **Guideline 7: Communication of Results**

In their last guideline Hevner et al. (2004, p. 90) underline the importance to communicate the results to a research-, a technology- and a management-oriented audience. Fortunately the relatively extensive space in a thesis allows to cater to all this perspectives. For the research-oriented audience the procedure is described in detail in Chapter 4 with the results in Chapter 5. The technology-oriented audience might be interested most in the implementation of the KEPTool as presented in Chapter 3.
For the management-oriented reader also the results in Chapter 5 might be of most interest, but also the summary of the results in Section 5.7.

As recommended by Hevner et al. (2004, p. 82) all guidelines have been considered in this thesis. One may conclude this thesis as design science research.
Bibliography


Maier, Ronald, Thalmann, Stefan, Bayer, Florian, Krüger, Michael, Nitz, Hendrik, and Sandow, Alexander. Optimizing Assignment of Knowledge Workers to Office


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A.6 Expert rating of complexity (cTP,a) and reusability of topic (rTP,a)  
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A Appendix

A.1 Parameters and Weights of the KEP Model

This section summarises the parameters and weights of the KEP Model. In Section 2.1 an informal description of the KEP Model can be found. A mathematical description is given in Section 3.2. Table A.1 shows all input parameters. Table A.2 gives an overview over the weights in the KEP Model, together with the conditions, they are subject to. Table A.3 shows the definition of parameters based on the input parameters in Table A.1 and the weights in Table A.2.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$i_{tp}$</td>
</tr>
<tr>
<td>2</td>
<td>$i_{ty}$</td>
</tr>
<tr>
<td>3</td>
<td>$n_a$</td>
</tr>
<tr>
<td>4</td>
<td>$c_{tp,a}$</td>
</tr>
<tr>
<td>5</td>
<td>$c_{ty,a}$</td>
</tr>
<tr>
<td>6</td>
<td>$e_{tp,e}$</td>
</tr>
<tr>
<td>7</td>
<td>$e_{ty,e}$</td>
</tr>
<tr>
<td>8</td>
<td>$e_{a,e}$</td>
</tr>
<tr>
<td>9</td>
<td>$m_{tp}$</td>
</tr>
<tr>
<td>10</td>
<td>$m_{ty}$</td>
</tr>
<tr>
<td>11</td>
<td>$mea$</td>
</tr>
<tr>
<td>12</td>
<td>$ts_{ty,a}$</td>
</tr>
<tr>
<td>13</td>
<td>$q_{tp,a}$</td>
</tr>
<tr>
<td>14</td>
<td>$mq_{ty,a}$</td>
</tr>
<tr>
<td>15</td>
<td>$r_{tp,a}$</td>
</tr>
<tr>
<td>16</td>
<td>$r_{ty,a}$</td>
</tr>
<tr>
<td>17</td>
<td>$s_{k,a}$</td>
</tr>
<tr>
<td>18</td>
<td>$f_{ty,a}$</td>
</tr>
<tr>
<td>19</td>
<td>$c_{pe}$</td>
</tr>
</tbody>
</table>

Table A.1: Parameters of the KEP Model.
### Table A.2: Weights in the KEP Model

<table>
<thead>
<tr>
<th>Weight</th>
<th>Description</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\alpha_{tp}$</td>
<td>$\alpha_{tp} + \alpha_{ty} = 1$</td>
</tr>
<tr>
<td>2</td>
<td>$\alpha_{ty}$</td>
<td>$\alpha_{tp} + \alpha_{ty} = 1$</td>
</tr>
<tr>
<td>3</td>
<td>$\alpha$</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>$\beta$</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>$\gamma_{tp}$</td>
<td>$\gamma_{tp} + \gamma_{ty} = 1$</td>
</tr>
<tr>
<td>6</td>
<td>$\gamma_{ty}$</td>
<td>$\gamma_{tp} + \gamma_{ty} = 1$</td>
</tr>
<tr>
<td>7</td>
<td>$\gamma$</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>$\delta_{tp}$</td>
<td>$\delta_{tp} + \delta_{ty} + \delta_a = 1$</td>
</tr>
<tr>
<td>9</td>
<td>$\delta_{ty}$</td>
<td>$\delta_{tp} + \delta_{ty} + \delta_a = 1$</td>
</tr>
<tr>
<td>10</td>
<td>$\delta_a$</td>
<td>$\delta_{tp} + \delta_{ty} + \delta_a = 1$</td>
</tr>
<tr>
<td>11</td>
<td>$\delta$</td>
<td>$\delta &gt; 0$</td>
</tr>
<tr>
<td>12</td>
<td>$\epsilon$</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>$\eta$</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>$\rho$</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>$\theta_{tp}$</td>
<td>$\theta_{tp} + \theta_{ty} = 1$</td>
</tr>
<tr>
<td>16</td>
<td>$\theta_{ty}$</td>
<td>$\theta_{tp} + \theta_{ty} = 1$</td>
</tr>
<tr>
<td>17</td>
<td>$\theta$</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>$\rho$</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>$\sigma$</td>
<td></td>
</tr>
</tbody>
</table>

### Table A.3: Computed parameters of the KEP Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 $i_k$</td>
<td>$\alpha_{tp} \cdot i_{fp}(tp) + \alpha_{ty} \cdot i_{fs}(ty)$</td>
</tr>
<tr>
<td>2 $c_{k,a}$</td>
<td>$\gamma_{tp} \cdot c_{fp}(k,a) + \gamma_{ty} \cdot c_{fs}(k,a)$</td>
</tr>
<tr>
<td>3 $e_{k,a,e}$</td>
<td>$\delta_{tp} \cdot e_{fp}(k,e) + \delta_{ty} \cdot e_{fs}(k,e) + \delta_a \cdot e_{a,e}$</td>
</tr>
<tr>
<td>4 $r_{k,a}$</td>
<td>$\theta_{tp} \cdot r_{fp}(k,a) + \theta_{ty} \cdot r_{fs}(k,a)$</td>
</tr>
</tbody>
</table>

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A.2 Future Work

This section highlights some directions for future work for the KEP Model. For adaptation criteria, the preparation may happen automatically or manually. Currently, this is not adequately represented in the model. Following is a counter example, where the KEP Model arrives at a not optimal solution.

Therefore, one assumes the ratings of knowledge elements $K_1, K_2$ are the same. They have the same benefit and the same effort is required to adapt them either automatically with $A_1$ or manually with $M_1$. The additional knowledge element $K_3$ emphasises the selection. Next, the benefit and effort for each knowledge element with respect to preparation tasks are given

<table>
<thead>
<tr>
<th>Knowledge Element</th>
<th>Task</th>
<th>Benefit</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_1$</td>
<td>$A_1$</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>$K_2$</td>
<td>$A_1$</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>$K_1$</td>
<td>$M_1$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>$K_2$</td>
<td>$M_1$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>$K_3$</td>
<td>$A_2$</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Then, if only one employee is present and he or she has the total capacity of 6, the difference between the benefit and effort is maximised by the following selection of $K_1, K_2$ both adapted by the task $M_1$, as can be seen by the following table.

<table>
<thead>
<tr>
<th>Knowledge Element</th>
<th>Task</th>
<th>Benefit</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_1$</td>
<td>$M_1$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>$K_2$</td>
<td>$M_1$</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

8 6

But, if one considers, that the effort for $A_1$ is divided between $K_1$ and $K_2$ one arrives at the following selection of $K_1, K_2$ with the task $A_1$ and the additional selection of $K_3$ with $A_2$. This yields a higher difference between benefit and effort and is thus preferable.

<table>
<thead>
<tr>
<th>Knowledge Element</th>
<th>Task</th>
<th>Benefit</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_1$</td>
<td>$A_1$</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>$K_2$</td>
<td>$A_1$</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>$K_3$</td>
<td>$A_2$</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

10 6
To counteract this behaviour, it is not possible to simply divide the effort without additional constraints as $K_1$ and $K_2$ have to be selected to gain. Further, preprocessing to find out, whether automatic or manual has less effort and discard the other does not achieve the goal. If one considers, e.g., in the same model capacity 4 where $M_1$ is discarded, because $A_1$ is better, one arrives at the suboptimal selection of only $K_3$.

Hence, one may consider the following proposed solution. A superficial knowledge element $\{K_1, K_2\}$ is added. For this knowledge element, the effort is equal to adapting only one of the knowledge element, but the benefit is added up. This requires to add the additional constraint that if $\{K_1, K_2\}$ is selected, then neither $K_1$ or $K_2$ can be selected.

<table>
<thead>
<tr>
<th>Knowledge Element</th>
<th>Task</th>
<th>Benefit</th>
<th>Effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>${K_1, K_2}$</td>
<td>$A_1$</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>$K_1$</td>
<td>$M_1$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>$K_2$</td>
<td>$M_1$</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>$K_3$</td>
<td>$A_2$</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

The presented observations provide a starting point for further investigation. They are not in the scope of the thesis, but may be valuable for future work.
A.3 Data Collection

A screenshot of the internal wiki page of the Layers Theory Camp, which served as basis for the collection of knowledge elements, can be seen in Figure A.1.

![Layers Theory Camp wiki page](image)

Figure A.1: Screen shot of the wiki page, which was the starting point for the collection of knowledge elements.

Table A.4 shows the collected knowledge elements from the Layers Theory Camp with their assigned topics and types.

<table>
<thead>
<tr>
<th>Name</th>
<th>Topic</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory Camp Flash</td>
<td>Organisation of the Theory Camp</td>
<td>Flash Meeting</td>
</tr>
<tr>
<td>Meeting 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theory Camp Flash</td>
<td>Organisation of the Theory Camp</td>
<td>Flash Meeting</td>
</tr>
<tr>
<td>Meeting 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theory Camp Flash</td>
<td>Organisation of the Theory Camp</td>
<td>Flash Meeting</td>
</tr>
<tr>
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<td>54 Response to underlying assumptions</td>
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</table>

Table A.4: Collected knowledge elements.
A.4 Questionnaire

The following cover letter presented the survey to the participants of the study.

Dear project partners,

for the Theory Camp in Aachen many artefacts, like videos, wiki pages or presentations, were created. A lot of effort was put into the creation! But, how could we and others benefit from these artefacts and how could we disseminate the results? This leads to the question, which of these artefacts should be further developed and adapted to user groups with their preferences?

At WP Leader Telco on 9th of September, we presented the KEPtool, Knowledge Element Preparation Tool, developed within LAYERS T3.2 by Maria Schett, a Decision Support tool, which supports the selection of multimedia artefacts for further preparations [1]. By using this tool we could get some answers to the question above and also gather input for the upcoming Theory Camp integration and consolidation activities as well as for the deliverable write up. Further, the results seem also valuable for the preparation of the upcoming project review.

Now we are looking for your support. We prepared a questionnaire to take your perspectives regarding this question into account. The collaborative rating will serve as input to the KEPtool and provide guidance for the selection process. The questionnaire will be online between Friday, 12th of September and Friday, 19th of September and will take approximately 5 minutes.

The questionnaire can be accessed here: www.soscisurvey.de/TheoryCamp

The results of the questionnaire will be presented at the Tallinn meeting. If you have any questions or suggestions, please do not hesitate to contact Maria (maria.schett@uibk.ac.at) or us directly.

Thank you very much in advance for your participation.
The UIBK Team

[1] https://docs.google.com/file/d/0B3KKeIy2Vk-9SFgwZUt5TTZDbjg/edit
Question [DM03] was reused from a previous survey conducted within the LL project (Deliverable 1.1, 2013, p. 68). Questions [DM01] and [DM02] are control questions.

### Demographics

1. **How would you characterise your role in the Learning Layers Project?**
   - [ ] Representative of application partner [DM03_01]
   - [ ] Representative of research partner [DM03_02]
   - [ ] Representative of technical partner [DM03_03]
   [multiple choice (0..3)]

2. **How extensive was your involvement in the Layers Theory Camp?**
   - [ ] I attended the Theory Camp in Aachen in person or remotely. [DM01_01]
   - [ ] I prepared content for the Layers Theory Camp. [DM01_02]
   - [ ] I was involved in the organisation of the Layers Theory Camp. [DM01_03]
   - [ ] I actively followed the developments of the Layers Theory Camp. [DM01_04]
   - [ ] I hardly followed the developments of the Layers Theory Camp. [DM01_05]
   - [ ] Other: __________ [DM01_06]
   [multiple choice (1..6)]

3. **How familiar are you with the artefacts developed at the Layers Theory Camp?**
   - [ ] I know the artefacts.
   - [ ] I have a general idea about the artefacts.
   - [ ] I am uninformed about the artefacts.
   - [ ] Other: __________
   [selection of 1]
### Importance of Topics

4. **How important do you deem the following topics of the Layers Theory Camp for the Learning Layers Project?**

<table>
<thead>
<tr>
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[TO01]
### Importance of Types

5. **How important do you deem the following types of media for disseminating the results of the Theory Camp?**

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[selection of 1 per line]
### Preparation Task

6. **According to which dimension should the artefacts be prepared?**

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<th>Option 3</th>
<th>Option 4</th>
<th>Option 5</th>
<th>Option 6</th>
<th>Option 7</th>
<th>Option 8</th>
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</thead>
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<td>methods considering recipient’s preferences and cognitive abilities during learning, e.g., a version with many practical examples is prepared</td>
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<td>ability or preference of a recipient for the language that is used for content delivery, e.g., a German version is prepared</td>
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<td>preferences for the style in which contents are delivered, e.g., a version with a specific font and colours is prepared</td>
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<td>knowledge of the recipient, acquired in the past and relevant for accessing the artefacts, which has to be considered for the information provision, e.g., a version with additional explanations of basic terms is prepared</td>
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[selection of 1 per line]

7. **Can you think of any other preparation task?**

7.1 ______________________

[free mention (0..16)]
8. **Last Question**: Would you like to support us further and participate in the follow-up telephone interview (~30 minutes)?

   *If so, please enter your e-mail address here. Please be aware, that then your e-mail address will be associated with your answers to discuss your results in the interview.*

   [optional e-mail address]
## A.5 Ratings

Figure A.2 shows the summary of the topics, types, and adaptation criteria the experts were supplied with for the effort rating.

![Cheat Sheet](https://htk.tlu.ee/layers/MW/index.php/Layers_Theory_Camp)

Figure A.2: Summary provided to the experts for guidance.
Table A.5 shows the ratings for the minutes of work an employee is expected to work for each standard unit in Table 4.10 and adaptation criterion in Table 4.3.

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Table A.5: Rating for the size of knowledge elements ($s_{k,a}$).

Table A.6 shows the ratings of complexity ($c_{tp,a}$) and reusability of topic ($r_{tp,a}$) from the domain expert.

<table>
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<td>Social Semantic Server</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Claims Matrix for Documenting Design and Empirical Work</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Collective and Networked Learning Theories</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Generation of Meaning</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Integrated Scaffolding Concept</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Knowledge Representation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Learning and Practices</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Models Used in Other Projects</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Language</td>
<td>Organisation of the Theory Camp</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>Organisational Learning</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>Research and Design Methods</td>
<td>1</td>
<td>1</td>
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<td>Language</td>
<td>Social Semantic Server</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Claims Matrix for Documenting Design and Empirical Work</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Collective and Networked Learning Theories</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Generation of Meaning</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Integrated Scaffolding Concept</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Presentation Preference</td>
<td>Knowledge Representation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Learning and Practices</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Models Used in Other Projects</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Presentation Preference</td>
<td>Organisation of the Theory Camp</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Organisational Learning</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Presentation Preference</td>
<td>Research and Design Methods</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Presentation Preference</td>
<td>Social Semantic Server</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Claims Matrix for Documenting Design and Empirical Work</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
## Previous Knowledge Generations of Meaning

- Collective and Networked Learning Theories
- Generation of Meaning
- Integrated Scaffolding Concept
- Knowledge Representation
- Learning and Practices
- Models Used in Other Projects
- Organisation of the Theory Camp
- Organisational Learning
- Research and Design Methods
- Social Semantic Server

### Table A.6: Expert rating of complexity ($c_{tp,a}$) and reusability of topic ($r_{tp,a}$).

<table>
<thead>
<tr>
<th>Adaptation Criterion</th>
<th>Topic</th>
<th>$c_{tp,a}$</th>
<th>$r_{tp,a}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Knowledge</td>
<td>Collective and Networked Learning Theories</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Generation of Meaning</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Integrated Scaffolding Concept</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Knowledge Representation</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Learning and Practices</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Models Used in Other Projects</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Organisation of the Theory Camp</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Organisational Learning</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Research and Design Methods</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Previous Knowledge</td>
<td>Social Semantic Server</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

The following Table A.7 shows the ratings of the complexity of a type with respect to an adaptation criterion ($c_{ty,a}$), the tool support ($ts_{ty,a}$), the expected quality ($q_{ty,a}$), the maximal feasible level of quality ($mq_{ty,a}$), the feasibility of preparation ($f_{ty,a}$), and the potential for reuse of preparation tasks ($r_{ty,a}$) from the technical expert.

### Table A.7: Expert rating of complexity ($c_{ty,a}$), tool support ($ts_{ty,a}$), expected quality ($q_{ty,a}$), maximal feasible level of quality ($mq_{ty,a}$), feasibility of preparation ($f_{ty,a}$), and potential for reuse of preparation tasks ($r_{ty,a}$).

<table>
<thead>
<tr>
<th>Adaptation Criterion</th>
<th>Type</th>
<th>$c_{ty,a}$</th>
<th>$ts_{ty,a}$</th>
<th>$q_{ty,a}$</th>
<th>$mq_{ty,a}$</th>
<th>$f_{ty,a}$</th>
<th>$r_{ty,a}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Requirements</td>
<td>Article</td>
<td>0.5</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Device Requirements</td>
<td>Flash Meet.</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Device Requirements</td>
<td>Presentation</td>
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<td>0.7</td>
<td>3</td>
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<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Device Requirements</td>
<td>Spreadsheet</td>
<td>1.5</td>
<td>0.8</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Device Requirements</td>
<td>Video</td>
<td>0.8</td>
<td>0.5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Device Requirements</td>
<td>Wiki Page</td>
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<td>0.6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Didactical Approach</td>
<td>Article</td>
<td>1</td>
<td>0.8</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
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<td>Flash Meet.</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
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<tr>
<td>Didactical Approach</td>
<td>Presentation</td>
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<td>0.8</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Didactical Approach</td>
<td>Spreadsheet</td>
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<td>0.9</td>
<td>3</td>
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<td>1</td>
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</tr>
<tr>
<td>Didactical Approach</td>
<td>Video</td>
<td>1.3</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0.8</td>
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<tr>
<td>Didactical Approach</td>
<td>Wiki Page</td>
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<td>0.6</td>
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<td>1</td>
<td>1</td>
<td>0.6</td>
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<tr>
<td>Language</td>
<td>Article</td>
<td>1</td>
<td>0.6</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>Language</td>
<td>Flash Meet.</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Table A.7: Expert rating of the complexity of a type ($c_{ty,a}$), the tool support ($ts_{ty,a}$), the expected quality ($q_{ty,a}$), the maximal feasible level of quality ($mq_{ty,a}$), the feasibility of preparation ($f_{ty,a}$), and the potential for reuse of preparation tasks ($r_{ty,a}$).

The following Tables show the ratings for the experience of the employees with respect to topic ($ex_{tp,e}$) in Table A.8, with respect to type ($ex_{ty,e}$) in Table A.9, and with respect to adaptation criterion ($ex_{a,e}$) in Table A.10.
<table>
<thead>
<tr>
<th>Employee</th>
<th>Topic</th>
<th>( e_{tp,e} )</th>
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</thead>
<tbody>
<tr>
<td>Alice</td>
<td>Organisational Learning</td>
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<tr>
<td>Alice</td>
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<td>1.25</td>
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<td>2</td>
</tr>
<tr>
<td>Alice</td>
<td>Knowledge Representation</td>
<td>1.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Claims Matrix for Documenting Design and Empirical Work</td>
<td>2</td>
</tr>
<tr>
<td>Bob</td>
<td>Collective and Networked Learning Theories</td>
<td>1.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Generation of Meaning</td>
<td>1.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Integrated Scaffolding Concept</td>
<td>1.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Learning and Practices</td>
<td>1</td>
</tr>
<tr>
<td>Bob</td>
<td>Models Used in Other Projects</td>
<td>2</td>
</tr>
<tr>
<td>Bob</td>
<td>Organisation of the Theory Camp</td>
<td>0.8</td>
</tr>
<tr>
<td>Bob</td>
<td>Organisational Learning</td>
<td>0.75</td>
</tr>
<tr>
<td>Bob</td>
<td>Research and Design Methods</td>
<td>1.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Social Semantic Server</td>
<td>2</td>
</tr>
<tr>
<td>Bob</td>
<td>Knowledge Representation</td>
<td>1</td>
</tr>
</tbody>
</table>

Table A.8: Expert rating for experience with topics \((e_{tp,e})\).

<table>
<thead>
<tr>
<th>Employee</th>
<th>Type</th>
<th>( e_{ty,e} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>Article</td>
<td>1</td>
</tr>
<tr>
<td>Alice</td>
<td>Flash Meeting</td>
<td>1</td>
</tr>
<tr>
<td>Alice</td>
<td>Presentation</td>
<td>0.8</td>
</tr>
<tr>
<td>Alice</td>
<td>Spreadsheet</td>
<td>0.75</td>
</tr>
<tr>
<td>Alice</td>
<td>Video</td>
<td>0.75</td>
</tr>
<tr>
<td>Alice</td>
<td>Wiki Page</td>
<td>0.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Article</td>
<td>0.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Flash Meeting</td>
<td>1</td>
</tr>
<tr>
<td>Bob</td>
<td>Presentation</td>
<td>0.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Spreadsheet</td>
<td>0.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Video</td>
<td>0.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Wiki Page</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table A.9: Expert rating for experience with types \((e_{ty,e})\).
<table>
<thead>
<tr>
<th>EMPLOYEE</th>
<th>ADAPTATION CRITERION</th>
<th>$e_{x_a,e}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alice</td>
<td>Device Requirements</td>
<td>2</td>
</tr>
<tr>
<td>Alice</td>
<td>Didactical Approach</td>
<td>0.5</td>
</tr>
<tr>
<td>Alice</td>
<td>Language</td>
<td>0.5</td>
</tr>
<tr>
<td>Alice</td>
<td>Presentation Preference</td>
<td>0.75</td>
</tr>
<tr>
<td>Alice</td>
<td>Previous Knowledge</td>
<td>1</td>
</tr>
<tr>
<td>Bob</td>
<td>Device Requirements</td>
<td>1.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Didactical Approach</td>
<td>1.1</td>
</tr>
<tr>
<td>Bob</td>
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<td>0.75</td>
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<tr>
<td>Bob</td>
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<td>0.5</td>
</tr>
<tr>
<td>Bob</td>
<td>Previous Knowledge</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Table A.10: Expert rating for experience with adaptation criteria ($e_{x_a,e}$).
A.6 Proposal

Table A.11 shows the proposal the KEPTool computed for the Layers Theory Camp.

<table>
<thead>
<tr>
<th>Knowledge Element</th>
<th>Adaptation Criterion</th>
<th>Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Aachen Theory Camp Video 2</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>2 Aachen Theory Camp Video 3</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>3 Aachen Theory Camp Video 4</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>4 Communities of Practice</td>
<td>Device Requirements</td>
<td>Alice</td>
</tr>
<tr>
<td>5 Communities of Practice</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>6 Aachen Theory Camp Video 6</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>7 Network Theory</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>8 Network Theory</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>9 Connectionism and niche interrelations</td>
<td>Presentation Preference</td>
<td>Bob</td>
</tr>
<tr>
<td>10 Absorptive Capacity</td>
<td>Device Requirements</td>
<td>Alice</td>
</tr>
<tr>
<td>11 Absorptive Capacity</td>
<td>Didactical Approach</td>
<td>Alice</td>
</tr>
<tr>
<td>12 Absorptive Capacity</td>
<td>Language</td>
<td>Alice</td>
</tr>
<tr>
<td>13 Absorptive Capacity</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>14 Absorptive Capacity</td>
<td>Previous Knowledge</td>
<td>Alice</td>
</tr>
<tr>
<td>15 Knowledge Sharing</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>16 Knowledge Sharing</td>
<td>Didactical Approach</td>
<td>Alice</td>
</tr>
<tr>
<td>17 Knowledge Sharing</td>
<td>Language</td>
<td>Alice</td>
</tr>
<tr>
<td>18 Knowledge Sharing</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>19 Knowledge Sharing</td>
<td>Previous Knowledge</td>
<td>Alice</td>
</tr>
<tr>
<td>20 ATLAS Theory</td>
<td>Device Requirements</td>
<td>Alice</td>
</tr>
<tr>
<td>21 Aachen Theory Camp Video 11</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>22 Learning in Clusters</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>23 Learning in Clusters</td>
<td>Language</td>
<td>Bob</td>
</tr>
<tr>
<td>24 Learning in Clusters</td>
<td>Presentation Preference</td>
<td>Bob</td>
</tr>
<tr>
<td>25 Learning in Clusters</td>
<td>Previous Knowledge</td>
<td>Bob</td>
</tr>
<tr>
<td>26 Complexity Theory</td>
<td>Device Requirements</td>
<td>Alice</td>
</tr>
<tr>
<td>27 Complexity Theory</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>28 Co-design</td>
<td>Device Requirements</td>
<td>Alice</td>
</tr>
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<td>Knowledge Element</td>
<td>Adaptation Criterion</td>
<td>Employee</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------------------</td>
<td>----------</td>
</tr>
<tr>
<td>29 Representational semantic networks vs. dynamic semantic networks</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>30 Hammer biases in CSCW and CSCL</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>31 Hammer biases in CSCW and CSCL</td>
<td>Presentation Preference</td>
<td>Bob</td>
</tr>
<tr>
<td>32 WP5 Matrix</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>33 WP4 Version</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>34 Response to underlying assumptions</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>35 Response to underlying assumptions</td>
<td>Presentation Preference</td>
<td>Alice</td>
</tr>
<tr>
<td>36 Aachen Theory Camp</td>
<td>Device Requirements</td>
<td>Bob</td>
</tr>
<tr>
<td>37 Aachen Theory Camp</td>
<td>Presentation Preference</td>
<td>Bob</td>
</tr>
</tbody>
</table>

Table A.11: Proposal computed for the Layers Theory Camp.
A.7 Interview Material

The following invitation was sent to the experts, who indicated in the questionnaire that they are interested in a follow-up interview.

Hello __________,
	hank you for participating in my survey! You indicated in the KEP questionnaire your willingness to participate in the follow-up evaluation.

A little more detail: I developed the KEPtool, Knowledge Element Preparation Tool, within LAYERS T3.2. It is a Decision Support tool, which supports the selection of multimedia artefacts for further preparations and will be later used in the NNB exhibition scenario. We collected the input ratings for the KEPtool through the questionnaire you participated in and additional expert interviews. Now we are able to run the KEPtool and it will propose artefacts which are best fit for preparation.

To evaluate the KEPtool I would like to interview you to evaluate the generated output and the process, i.e., how this output was achieved.

For me, it would be ideal, if you could propose a suitable date (30 minutes) between Monday, 6th of October and Wednesday, 8th of October. If those dates don’t suit you, please indicate, when it would work best for you (before 10th of October).

Would you prefer to do the interview via Skype or via telephone?

Thank you again for your time and support,

Maria Schett
Figure A.3 shows the interview guideline, which was sent out to the participants of the evaluation prior to the interview.

**Interview Foundations**

**Background:** The Knowledge Element Preparation Model (KEP model), and its implementation the KEPool, have been developed to support a decision maker to find knowledge elements, which are best suited for preparation according to adaptation criteria. The KEPool has been applied to the knowledge elements created throughout the Layers Theory Camp. Through the survey you participated in (Figure 1), and expert interviews within the Learning Layers project, ratings as input for the KEPool have been collected. Then the KEPool computed a proposal for preparing some of the knowledge elements with respect to the adaptation criteria (1) device requirements, (2) didactical approach, (3) language, (4) presentation preference, (5) previous knowledge.

**Figure 1: Screenshots from the Survey**

**Study Objectives:**

- to evaluate the proposal generated by the KEPool for the Layers Theory Camp
- to evaluate the influencing factors of the KEP model, and
- to investigate future developments and applications for the KEPool

**Interviewer:** I am a master student and research assistant at the University of Innsbruck in the Department of Information Systems. My original background is a Bachelor degree in Computer Science. Afterwards, I continued with a master in Information Systems and in Computer Science. Since March 2013 I work within the EU FP7 research project Learning Layers.

For further information please contact: maria.schett@uibk.ac.at
Interview Agenda

1. Factors in the KEP model [10 min]
I will give a brief presentation of the KEP model and the KEPtool. Then we will investigate the factors, which influence the proposal. The questions will be:
- Do you consider one of these factors more important than the others?
- Do you consider another factor representing a benefit/effort important?
- What was your reasoning during the rating of importance and need in the survey?

2. Proposal of the KEPtool [10 min]
We will investigate the proposal of the KEPtool for the Layers Theory Camp. The questions will be:
- What is your first impression of the proposal from the KEPtool?
- Is there anything surprising?
- What do you think about the proposal?

3. Outlook for KEPtool [10 min]
We will investigate the future of the KEPtool. The questions will be:
- Do you consider the proposal valuable for disseminating the Layers Theory Camp results?
- Can you imagine other situations where the KEPtool could be applied and what could be benefits of applying it?
- Do you see any specific requirements for the user interface for the KEPtool?
In the following Figure A.4, the presentation, which was shared with the participants throughout the interview (cf. Chapter 4) is given.

![Evaluation: KEP Model & KEPtool](http://Learning-Layers.eu)

**Evaluation: KEP Model & KEPtool**

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**Agenda**

1. Introduction: KEP model / KEPtool {10 min}
2. Proposal by KEPtool for Layers Theory Camp {10 min}
3. Outlook: KEPtool {10 min}
**KEPtool: Benefits**

- importance of topic or type
- need of an adaptation criterion

**KEPtool: Effort**

- complexity of a topic or type
- experience of an employee
- tool support
- expected quality
- re-usability of preparation tasks
KEPtool: Proposal

(1) device requirements
(2) didactical approach
(3) language
(4) presentation preference
(5) previous knowledge

Proposal

1. Result for Collaborative Rating

2. Result for Your Rating
Figure A.4: Presentation shared in the interview.
Eidesstattliche Erklärung

Ich erkläre hiermit an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe. Alle Stellen, die wörtlich oder inhaltlich den angegebenen Quellen entnommen wurden, sind als solche kenntlich gemacht.

Die vorliegende Arbeit wurde bisher in gleicher oder ähnlicher Form noch nicht als Magister-/Master-/Diplomarbeit/Dissertation eingereicht.

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