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PROCEDURE FOR SELECTING KNOWLEDGE ELICITATION METHODS WITH REGARD TO KNOWLEDGE TYPES

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ABSTRACT
The intention of this paper is to propose a procedure that illustrates how elicitation methods appropriate for knowledge types (domains) might be selected. Analysing existing literature suggests that it is mostly possible to provide a statement about more frequently used knowledge acquisition methods. Furthermore, there are studies that show that certain knowledge acquisition methods are significantly more efficient than others. The attempt to link knowledge acquisition methods and knowledge itself is still missing.
For this purpose, knowledge types have been analysed according to their content. As a result, it is possible to assign specific characteristics to each knowledge type. Furthermore, each acquisition method offers specific abilities. This paper discusses how acquisition methods and their related abilities should be connected with the specific characteristics of knowledge types. Thus, the proposed procedure helps knowledge engineers to identify the suitable acquisition method for specific knowledge types.

Keywords: knowledge management, design methods, knowledge acquisition, knowledge types

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1 INTRODUCTION

At the beginning of the nineties, many industrialised nations identified themselves as "information societies" to express the idea that information is the determining factor of production. For some years now, it has not been sufficient to assess the accessibility of information alone. There is a need to evaluate, to identify and understand, and to administer essential information. The information itself is not important, rather the knowledge derived from the information and a specific context. Within the new "knowledge society", knowledge is a factor of production (Zahn, 1998). Thus, knowledge has to be managed in order to sensitively develop it in an effective and target-oriented manner (Roth et al., 2012). Awareness of required and existing knowledge in companies represents the potential to enhance the whole product development process by focusing on product development.

Based on these considerations and the aim of gaining an understanding of existing knowledge, it is necessary to start with a general overview of what knowledge management is. In literature, slight variances of opinion regarding knowledge management exist. Figure 1 reveals common parts of knowledge management building on the work of Probst et al. (2006), for example, and Roth et al. (2012).

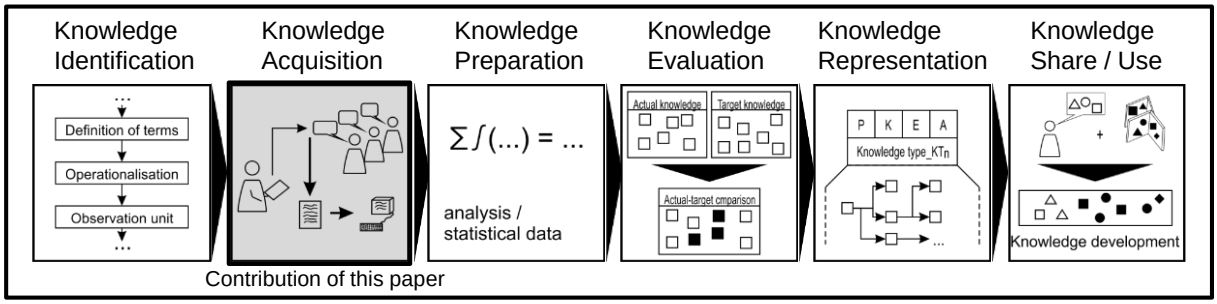

Figure 1. Field of knowledge management and related integration of this contribution

As stated in Shadbolt and Burton (1989), "a significant obstacle to the construction of knowledge-based systems is the process of knowledge acquisition". Knowledge-based systems support highly knowledge-intensive tasks within the area of codified knowledge management. Gebus and Leiviskä (2009) recognise difficulties for companies facing the challenge of creating systems for acquiring, retaining and assessing knowledge, especially in the case of highly specialised knowledge. Authors often describe the step for acquiring knowledge for a special domain as the critical bottleneck (e.g. Chu and Wang, 2008 and Hua, 2008). Regarding the literature, it can be stated that a lot of research has been done in the field of knowledge management, especially in the area of knowledge acquisition techniques and methods. Inter alia Gebus and Leiviskä (2009) realise that "knowledge exists in any organisation and can take various forms. […] Experts possess many different types of knowledge and numerous techniques have been developed to facilitate the extraction process." In an initial step towards standardising the knowledge acquisition process, a so-called "problem-task-representation-acquisition map" has been developed in a much generalised form by Holsapple et al. (1989). Wagner et al. (2003) offer a content analysis, focusing on the usage of knowledge acquisition techniques and also on the problem domain that the application addresses. Wagner et al. observe that several knowledge techniques have not been used within the more than 90 expert system applications analysed. Chu and Hwang (2008) list, for example, approximately 20 knowledge acquisition tools and methods that have been developed to deal with the knowledge acquisition problem. Hua (2008) offers initial guidance as to how and when knowledge acquisition techniques should be used within a knowledge acquisition project. It involves 8 general steps with superordinate aspects for selecting knowledge acquisition techniques. However, the problematic of how to identify knowledge acquisition techniques suitable for the acquired knowledge has not been considered in more detail. In the next section, the problem statement and goals of this contribution will be presented.

2 PROBLEM STATEMENT AND GOALS

This paper can be categorised within the area of knowledge management and is focused on knowledge acquisition (cf. Figure 1). The last statement in Section 1 in particular deserves more detailed consideration. As yet, no procedure exists for identifying the appropriate acquisition method

depending on the knowledge to be acquired. It is mostly possible to provide a statement about more frequently used knowledge acquisition methods (cf. Wagner et al., 2003). Also, there are studies that show that certain knowledge acquisition methods are significantly more efficient than others (Wagner et al., 2001). The attempt to link "active" knowledge acquisition methods and knowledge itself is still missing. Knowledge acquisition is still "an urgent problem of the expert systems and other knowledge systems" (Hua, 2008). However, the objective of this paper is not to provide a further method for acquiring knowledge.

According to Holsapple and Wagner (1996), knowledge elicitation and acquisition can sometimes be used interchangeably, but in the strictest sense knowledge elicitation should be viewed as one phase of knowledge acquisition. Within this paper, these terms are used synonymously. The preferred term used is elicitation method.

Summarising Section 1 and Section 2, the goal of this contribution is to offer a procedure for selecting knowledge elicitation methods based upon chosen knowledge types (domains) to be collected.

The paper is organised as presented in Table 1. In addition, Table 1 contains the main research question (MRQ) and corresponding sub-questions (RQ1/RQ2/RQ3) that should be answered within this contribution to address the aforementioned problems and goal.

Table 1. Overview of the contribution and corresponding questions answered

S = Section	(M)RQ = (Main) Research Question	
S 1		Introduction and contribution of this paper
S 2		Problem statement and goals
S 3	MRQ	Clarifying the task: "How might a procedure for selecting knowledge elicitation methods with regard to the knowledge types/domains look?"
S 3.1	RQ1	Knowledge types address specific knowledge domains: "What are the specific characteristics of knowledge types?"
S 3.2	RQ2	Inherent strengths and weaknesses of knowledge elicitation methods: "What are the limitations of knowledge elicitation methods or rather what are the abilities of knowledge elicitation methods?"
S 3.3	RQ3	The abilities of knowledge elicitation methods should be connected with the specific characteristics of knowledge types: "How can knowledge types be linked to elicitation methods for selecting matching variants – referring to RQ1 and RQ2?"
S 4		Application of the presented procedure as a first evaluation
S 5		Discussion of the results
S 6		Conclusion and outlook

3 PROCEDURE FOR SELECTING KNOWLEDGE ELICITATION METHODS

Section 3 aims to clarify the main task of this contribution: "How might a procedure for selecting knowledge elicitation methods with regard to the knowledge types (domains) look?" As stated in Section 2, existing knowledge elicitation methods mainly focus on how to acquire knowledge and how to optimise the methods. They do not offer specific assistance for selecting knowledge elicitation methods. This gap should be closed. Figure 2 represents the main idea of this contribution. On the one hand, there is a wide range of elicitation methods and on the other hand there is a great variety of knowledge types.

Each elicitation method offers specific possibilities in terms of abilities. For example, some methods are most capable when eliciting knowledge that depends on personal decisions based on implicit knowledge; others are more suitable for eliciting rather explicit domains such as factual knowledge.

Besides this, each knowledge type describes different facts. Depending on the field of application, it can be assumed that each knowledge type might be described by specific characteristics. It should be possible to develop those characteristics from common contributions such as Roth et al. (2010).

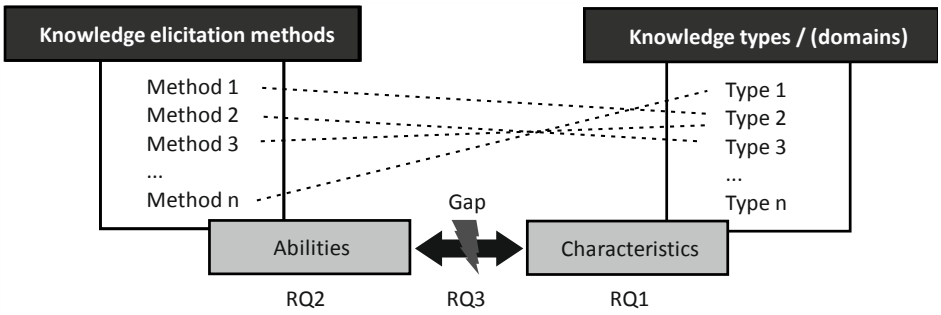

Figure 2. Main idea of the contribution – closing the gap

The development of the aforementioned procedure should produce the possibility of identifying knowledge elicitation methods in such a way that the corresponding abilities are suitable for acquiring the characteristics of the selected knowledge type. "Closing the gap" allows for a more target-oriented selection of elicitation methods.

3.1 Answering Research Question 1 – Focus on knowledge types (Step 1)

In the first step, the research question as to whether all knowledge types (or domains) have the same characteristics or if they have specific characteristics has to be answered. This can be followed by the question "What are the specific characteristics of knowledge types?" (RQ1). To this end, knowledge types have to be analysed. In order to answer this question, it is necessary to ensure the comprehensibility of the approach for the purpose of analysis as well as the comprehensibility of the results of the analysis. Keller and Binz (2009) demand that a "methodology must provide means of supporting the continuous documentation of the course of actions taken and the achieved results". Bearing this in mind, the analysis of knowledge types can be done following the content analysis as described in Krippendorf (1980), for example. A specific content (e.g. a text) "is coded or broken down into manageable categories on a variety of levels – word, word sense, phrase, sentence, or concept" (Wagner et al., 2003). Transferring the principle of the content analysis, results in the following procedure as shown in Figure 3.

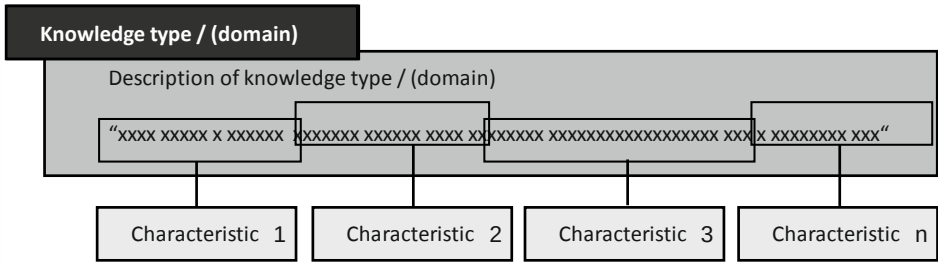

Figure 3. Deriving characteristics from knowledge types

The specific characteristics of the chosen knowledge type can be derived as characteristic $C_{1...n}$. Conducting this procedure results in a detailed matrix describing all selected knowledge types (Figure 4). Of course, not every knowledge type possesses the same characteristics. This should be illustrated on the right-hand side of the figure. Knowledge type 1 (KT_1) can be described with characteristics 1 (C_1) and 2 (C_2) whereas knowledge type 3 (KT_3) possesses only characteristic 1 (C_1).

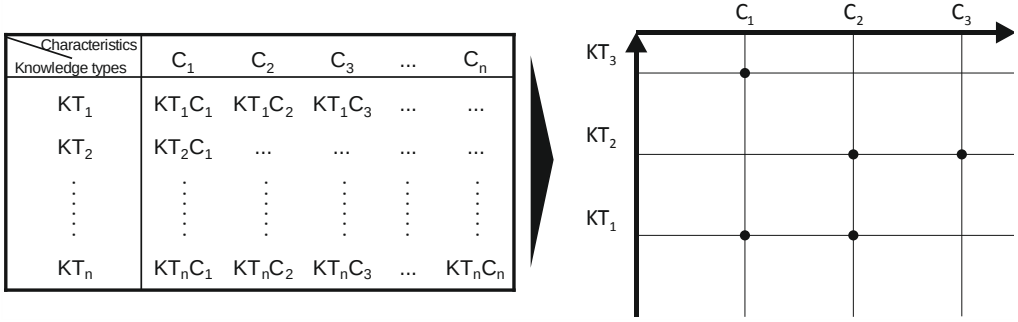

Figure 4. Assigning characteristics ($C_{1...n}$) to knowledge types ($KT_{1...n}$)

3.2 Answering Research Question 2 – Focus on acquisition methods (Step 2)

Section 3.2 deals with the fact that knowledge elicitation methods have inherent strengths and weaknesses. For this purpose, the research question "What are the limitations of knowledge elicitation methods or rather what are the abilities of knowledge elicitation methods?" (RQ2) arises. According to the statements made above, various knowledge elicitation methods exist in literature and praxis. Each method follows certain steps for achieving its personal goal. As well as the knowledge types, it should be possible to derive specific abilities from the descriptions and instructions of those methods. Therefore, it might be useful to analyse contributions such as Wagner et al. (2001, 2003), Hua (2008) and others. Figure 5 presents how a later matrix might look, performing the content analysis for several elicitation methods. The right-hand side of the figure states that, for this theoretical example, elicitation method 1 (E_1) has the abilities 1 (A_1) and 2 (A_2) for acquiring knowledge. Instead, elicitation method 3 (E_3) is only capable of eliciting knowledge with its ability 2 (A_2).

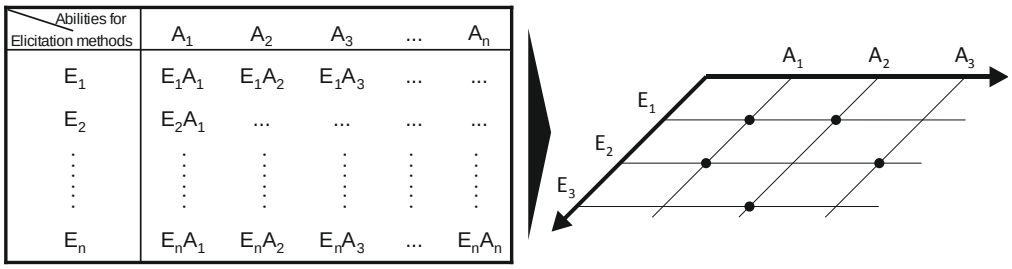

Figure 5. Assigning abilities for eliciting specific characteristics ($A_{1...n}$) to elicitation methods ($E_{1...n}$)

3.3 Answering Research Question 3 - Procedure for identifying and selecting eligible methods (Step 3)

Finally, this section discusses how knowledge elicitation methods should be connected with the specific characteristics of knowledge types. To be specific, this means that research question 3 (RQ3) "How can knowledge types be linked to elicitation methods for selecting matching variants?" has to be answered. For this purpose, it is necessary to consider knowledge elicitation methods and knowledge types simultaneously. Assigning abilities for acquiring a specific fact to characteristics describing a specific fact allows for the aggregation of both levels. In detail, this means that a

fact acquired by a specific ability ($A_{1...n}$) = fact described by a specific characteristic ($C_{1...n}$) (1)

Equation (1) results in Figure 6. The essential parts of Figures 4 and 5 are incorporated in a multi-level matrix. A comparison of both levels ($KT_{1...n}/C_{1...n}$ and $E_{1...n}/A_{1...n}$) reveals concurrences, highlighted with light grey nodal points. In order to give an example, Figure 6 considers explicitly the layer for knowledge type 1 (KT_1).

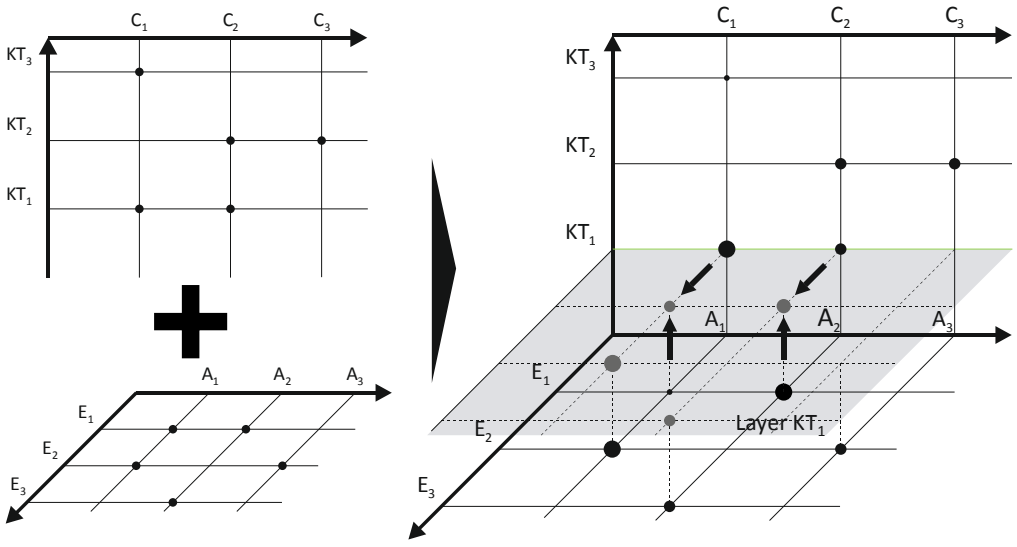

Figure 6. Assigning knowledge types ($KT_{1...n}$) and elicitation methods ($E_{1...n}$)

In addition, it can be determined that the nodal points can be of different sizes. This represents the possibility for taking into account that various knowledge types contain specific characteristics differently and that various elicitation methods contain specific abilities differently. It is proposed to distinguish between the following four degrees: no nodal point (no matching, e.g. KT_2/C_1), small nodal point (low distinctness, e.g. KT_3/C_1), middle nodal point (average distinctness, e.g. E_3/A_2), large nodal point (high distinctness, e.g. E_2/A_1).
As the next and final action, each layer has to be interpreted (phase of interpretation). This is done by summing up all individual results. The left-hand side of the multi-level matrix in Figure 7 contains the final results of the previously performed steps. Within the layer for knowledge type 1 (Layer KT_1), elicitation method 1 (E_1) seems to be the most appropriate method (largest nodal point). Elicitation method 3 (E_3) seems to be the least appropriate method.

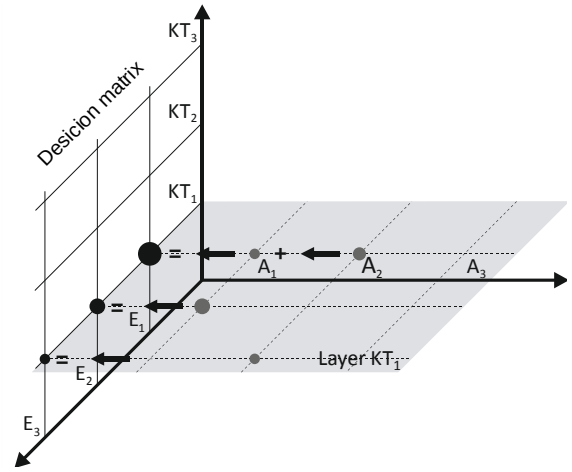

Figure 7. Phase of interpretation and "Decision matrix"

4. APPLICATION OF PRESENTED PROCEDURE AS FIRST EVALUATION

In Section 3, a general proposal for a procedure for selecting elicitation methods depending on the knowledge type is presented. In order to substantiate this proposal, the procedure consisting of 3 steps (Sections 3.1, 3.2 and 3.3) has been applied to a first research project. This project concentrates on evaluating knowledge within the product development process and deals in particular with product development knowledge. Knowledge types have been presented in Roth et al. (2012). This initial evaluation considers examples of knowledge types with strong contextual relationship in accordance with Roth et al. (2012). In the following, extracts of this application will be presented.
As presented in Section 3.1, the chosen knowledge types have to be analysed according to their content. As a result of this analysis, it was possible to identify 7 characteristics that are covered by the sum of the chosen knowledge types. Table 2 depicts these characteristics and offers short descriptions.

Table 2. Characteristics (C) of knowledge types (KT) and short descriptions

C_1	Overview / Structure	KT contains general facts and general information about a specific area
C_2	Detail	KT represents very detailed facts
C_3	Problem-solving process	KT is used for problem-solving-processes
C_4	Related to the past	KT represents actions/tasks performed in the past
C_5	Related to the future	KT represents actions/tasks concerning the future
C_6	Conditionality	KT supports decisions based on "what if" cases
C_7	Normativity	KT includes necessary reasons while performing a task

Table 3 assigns the characteristics from Table 2 to each knowledge type. For example, "business strategy knowledge comprises the general strategy of a company" (Roth et al., 2010). Based on this short definition and other more detailed descriptions, this knowledge type contains mainly the procedure to reach the vision of a company. Therefore, this knowledge type is related to future belongings (C_5). Furthermore, it must be capable of giving a summary (C_1) of and detailed insight (C_2) into the specific area as well as mapping "what if" cases (C_6).

In this way, the whole content analysis has been done for all selected knowledge types from Roth et al. (2012) and is presented in Table 3. The values in Table 3 constitute the degrees of distinctness introduced in Section 3.3. Management knowledge, for example, can be characterised with a high distinctness with characteristic 1 (C_1) and with an average distinctness with characteristic 2 (C_2). For this, the values in Table 3 introduce how pronounced each characteristic is for each knowledge type. As orientation for the interpretation, the value "1" indicates a high correlation with the characteristic, the value "0.5" a middle correlation with the characteristic and an empty field states that the specific knowledge type does not possess the related characteristic.

Table 3. Exemplary considered knowledge types (KT) and assigned characteristics (C)

		C_1	C_2	C_3	C_4	C_5	C_6	C_7
KT_1	Business strategy knowledge	0.5	0.5			1	0.5	
KT_2	Management knowledge	1	0.5					
KT_3	Practical knowledge			1				
KT_4	Operational knowledge			1				
KT_5	Conditional knowledge						1	
KT_6	Normative knowledge							1
KT_7	Expert knowledge	0.5	1	0.5				
KT_8	Experience knowledge				1			
KT_9	Business strategy knowledge				1			

In accordance with Section 3.2, it is necessary to analyse elicitation methods with respect to their abilities. Therefore, all relevant elicitation methods have to be collected. The selection of these methods is done in this particular example by examining existing literature. Shadbolt and Burton (1989) have identified four techniques (structured interview, protocol analysis, card sorts and laddered grids). However, Wagner et al. (2001) have identified the following methods as being the most common: unstructured interview, structured interviewing techniques, protocol analysis, psychological scaling and card sorting. Hua (2008) distinguishes the methods as follows: protocol generation techniques, protocol analysis techniques, matrix-based techniques, sorting techniques, limited information and constrained processing tasks as well as diagram-based techniques. Castellanos et al. (2011), on the other hand, differentiate as follows: direct approach, observational approach, indirect approach, machine-learning approach, document processing. Based on the aforementioned and further authors, in literature 35 elicitation methods have been identified as relevant within this project. Table 4 depicts the elicitation methods that are mainly relevant within the project, sorted by superordinate clustering criteria.

Table 4. Extract of elicitation methods (E) considered

Interview techniques	E_1	Unstructured interview
	E_2	Structured interview
Expert observation techniques	E_4	Protocol analysis
	E_6	Limited information tasks
	E_8	Retrospective case description
	E_9	Hypothetical cases
	E_{10}	Critical incident method
Reviewing techniques	...	
Cognitive-structured techniques	E_{15}	Repertory grid techniques
	E_{16}	Concept sorting
Language-based methods	...	
Other techniques	E_{28}	Forwards and backwards simulation
Processual knowledge elicitation methods	...	
System methods	...	

As presented in Section 3.2, the chosen elicitation methods have to be analysed according to their abilities. As a result of this analysis, it was possible to identify 11 abilities which are covered by the sum of the chosen 35 elicitation methods. Table 5 depicts these abilities and offers short descriptions.

Table 5. Abilities (A) of elicitation methods (E) and short descriptions

A_1	Overview / Structure	Ability to give an overview about a specific area
A_2	Detail	Ability to collect very detailed facts
A_3	Freedom during performance	Ability to influence the "course" of elicitation
A_4	Structured approach	Ability to proceed with a high degree of structure
A_5	Influence on expert	Ability to influence on expert while eliciting knowledge
A_6	Problem-solving process	Ability to consider problem-solving processes
A_7	Related to the past	Ability to consider actions/tasks related to the past
A_8	Related to the future	Ability to consider actions/tasks related to the future
A_9	Conditionality	Ability to consider "what if" cases
A_{10}	Normativity	Ability to detect reasons while performing a task
A_{11}	Revealing implicit knowledge	Ability to reveal implicit, non-explicit knowledge

Table 6 assigns the abilities from Table 5 to each knowledge elicitation method. For example, the retrospective case description (E_8) serves as a method for describing concrete cases in the past (A_7). This method also offers freedom during performance (A_3) and permits influence on experts (A_5). Furthermore, it is possible to support the problem-solving process (A_6) and to detect reasons while performing a task (A_{10}). The values in Table 6 introduce how pronounced each ability is for each elicitation method. As orientation for the interpretation, the value "2" indicates high ability, the value "-2" low ability.

Table 6. Abilities (A) assigned to knowledge elicitation methods (E)

		E_1	E_2	E_4	E_6	E_8	E_9	E_{10}	E_{15}	E_{16}	E_{28}
$A_1 = C_1$	Overview / Structure	2	1	-2	-2	-2	-2	-2	2	2	-2
$A_2 = C_2$	Detail	-1	1	2	0	-1	-1	-1	0	0	2
A_3	Freedom during performance	2	-2	1	1	1	1	1	0	0	0
A_4	Structured approach	-2	2	0	0	0	0	0	0	0	1
A_5	Influence on expert	2	2	-2	-2	1	1	1	0	0	1
$A_6 = C_3$	Problem-solving process	0	0	2	2	1	1	1	0	0	2
$A_7 = C_4$	Related to the past	0	0	0	0	2	-2	2	0	0	0
$A_8 = C_5$	Related to the future	0	0	0	0	-2	1	-2	0	0	0
$A_9 = C_6$	Conditionality	0	0	0	1	-2	2	-2	0	0	1
$A_{10} = C_7$	Normativity	0	0	1	1	1	1	1	0	0	2
A_{11}	Revealing implicit knowledge	-2	-2	1	1	0	0	0	0	0	0

Finally, executing the step proposed in Section 3.3, Table 7 presents the results modelled according to the decision matrix on the left-hand side of Figure 7. In order to gain a better understanding of these results, the table contains only the two most appropriate elicitation methods for each knowledge type. For example, knowledge type 1 (KT_1 = business strategy knowledge) ought to be elicited by using an unstructured (E_1) or a structured interviewing (E_2) technique. The size of the point in Table 7 represents the degree of representation. Using the elicitation method with the larger point is recommended.

Table 7. Decision matrix for selecting elicitation methods for each knowledge type

	KT_1	KT_2	KT_3	KT_4	KT_5	KT_6	KT_7	KT_8	KT_9
E_1	●	⬤							
E_2	⬤	⬤					●		
E_4			⬤	⬤			⬤		
E_6									
E_8								⬤	⬤
E_9					⬤				
E_{10}						●		⬤	⬤
E_{15}									
E_{16}									
E_{28}			●	●	⬤	⬤			

5 DISCUSSION OF THE RESULTS

Beginning with the findings gathered mainly in Section 3, all postulated sub-research questions have been answered in a satisfactory way. As a result of this contribution, a procedure for selecting knowledge elicitation methods with regard to their knowledge types (domains) has been introduced, following several steps. This means that in an initial step, a theoretical approach was developed in Section 3. The aim was to bring together elicitation methods and corresponding knowledge types. Critically, it must be added that this procedure expects a high level of understanding to be gathered concerning the knowledge types and of the elicitation methods. This procedure is only applicable if it is possible to split up both aspects into interpretable parts that allow statements to be made about the characteristics and abilities presented in Sections 3.1 and 3.2. Furthermore, it could be expected that the chosen results will never be completely objective. However, the clear and comprehensible steps contribute to the reduction of subjective elements. Section 4 offers a first application as an evaluation. Of course, it is not possible to present all results within this contribution. The attempt was to illustrate, by means of an example, the general applicability in a subjective manner. At this point, it can be stated that a selection of elicitation methods with respect to their knowledge types was successful. As mentioned earlier, the selected elicitation methods should be understood to be a proposal. It has not yet been verified that the results represent the most highly efficient method in each case. Regarding the existing literature, it is highly questionable whether this is possible at all. However, a short unplanned survey with 3 colleagues has been conducted. This is not quite representative but it seems as though the results received are not very far from reality.

Regarding Sections 3 and 4, it can be determined that the presented procedure has not been developed only for a specific use case. It should be emphasized that it is possible to adapt this procedure to many more knowledge types, characteristics, abilities and elicitation methods. Figure 8 represents this universality.

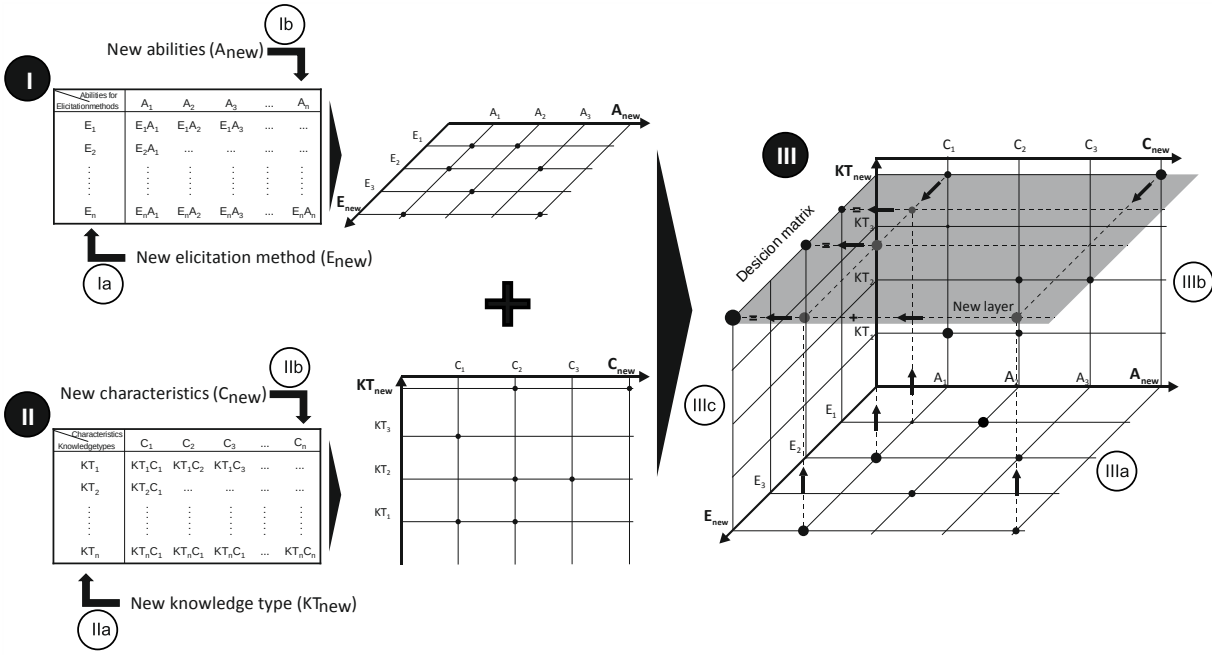

Figure 8. Universality – adaptable procedure for different use cases

In addition, important steps for adapting the procedure to new knowledge types and elicitation methods have been derived. These are as follows:

(I) Check existing elicitation method/ability matrix. Decision: extension necessary (yes/no).

If yes:

(Ia) Implement new elicitation method.

(Ib) Derive and implement new abilities (if available) while performing content analysis.

(II) Check existing knowledge type/characteristics matrix: Decision: extension necessary (yes/no).

If yes:

(IIa) Implement new knowledge type.

(IIb) Derive and implement new characteristics (if available) while performing content analysis.

(III) Extend existing multi-level matrix and check new elements:
(IIIa) Weigh up (if necessary) new nodal points within elicitation methods/ability matrix
(IIIb) Weigh up (if necessary) new nodal points within knowledge type/characteristics matrix
(IIIc) Execute interpretation of the new layer and complete the decision matrix.

6 CONCLUSION AND OUTLOOK

Summing up, this contribution presents a procedure that illustrates how elicitation methods appropriate for knowledge types (domains) might be selected. To this aim, a procedure with several steps has been presented. The resulting multi-level matrix has been applied to a first evaluation case. This application has then been discussed critically.

Consequently, it is surely necessary to do further research in the area of knowledge acquisition. Of course, a more detailed verification of the results (selected elicitation methods for each knowledge type) has to be done. The aim is to develop comprehensible and non-subjective methods for supporting common knowledge management processes.

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