Map of the Maps: Conceptualization of the Knowledge Maps

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Abstract

The company's knowledge assets and ability to coordinate them become increasingly critical. Knowledge maps can scaffold knowledge search and decision-making by creating visible links between knowledge, its application, source, and owner. The term Knowledge map was used with various meanings in several scientific communities: knowledge management, education studies, organization studies, decision analysis, artificial intelligence, etc.

The term itself is still rather vague. To generalize the variety of the definitions, one can use the term knowledge map as a description of the sources, flows, owners, and application areas of knowledge within the organization. The current study considers knowledge maps from a knowledge management perspective and is devoted to generalizing the numerous scattered knowledge mapping research and practices. It aims to identify and consolidate knowledge maps interpretations by analyzing their contents.

The discussed research results in developing the ontology of knowledge maps. Existing types of knowledge maps are associated with fragments of this ontology. The such ontology may help select the necessary building blocks (templates and elements) for knowledge mapping in specific companies and situations. The research methodology is based on literature review, semantic analysis, and ontological engineering. The paper also provides the knowledge mapping ontology application guidelines and demonstrates them via a case study.

Keywords

Knowledge maps, Templates, Ontology, Semantics, Knowledge management systems

1. Introduction

Modern industry, educational, and research organizations are burdened under data/knowledge flow. In light of the knowledge age, information overload research in the business context rises rapidly in many fields with various frameworks, methods, and subjects [1, 2]. This paper studies knowledge maps – special tools for knowledge analysis that can improve managerial decision-making and reduce the cognitive workload of knowledge workers. The knowledge maps can scaffold the knowledge search and decision-making by specifying what is known in the organization, where this knowledge is located, who knows what, and what for a company requires specific knowledge.

Since a knowledge map is usually a visual representation, it often links knowledge structure diagrams with other organizational diagrams and charts. It is the basis for determining knowledge commonality or areas where similar knowledge is used across multiple processes. The knowledge map as a "description of the sources, flows, constraints and sinks of knowledge within the organization" [3] can support the knowledge workers and decision-makers [4].

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The current study considers knowledge maps from a knowledge management perspective and is devoted to generalizing the numerous scattered knowledge mapping research and practices. “Knowledge management perspective” means that we do not include into the term “knowledge map” different knowledge diagrams – like mind maps, concept maps, flowcharts, etc. that depict the primary relations between the pieces of knowledge body.

The discussed research results in a conceptual model or ontology [5] for knowledge maps used in knowledge management. Such an ontology may help select the necessary elements for knowledge mapping in a specific company and situation.

Research in knowledge mapping is not so young and started in the late 90-ies. There are some generalizing works in this area, for example, an overview of the concept [6, 7], a classification of knowledge maps using different criteria (by purpose, by format, by content) [8], a systematic review of knowledge mapping research [9]. There are also some methodologies and frameworks for knowledge map’s structure and templates [10] (American Productivity & Quality Center). But there are no surveys devoted to the content ("what") of knowledge maps, which analyze typologies, examples, and templates of knowledge maps to identify possible components and building blocks of a knowledge map. This research fills the gap mentioned above.

2. Literature review

2.1. Knowledge maps typologies

Several different typologies of knowledge maps have arisen during the last two decades. The early developed ones have inconsistent classification parameters or describe only a tiny part of the knowledge maps variety. Further, we focus only on several mature classifications – we took Eppler’s typologies [7, 8] since they are highly cited in the academic community and APQC’s typology [10, 11], since APQC’s approach to knowledge management and mapping is rather famous and used in industry.

The classic of visual approach to knowledge management Martin J. Eppler proposes several extensive classifications of knowledge maps. A practical one [7] is:

1. Knowledge source maps (where the knowledge is),
2. Knowledge asset maps (what kind of knowledge we have),
3. Knowledge structure maps (how the knowledge is organized and interconnected),
4. Knowledge application maps (which knowledge is needed for performing activities, producing required results, and achieving goals),
5. Knowledge development maps (how certain knowledge is developed).

In his later work, Martin Eppler suggested a broader classification [8] which is more precise, rigid, and formal. That classification is multi-faceted as it includes several simple classifications, which are created based on different classification principles or facets:

1. by intended purpose or knowledge management process (‘‘why?’’), which includes knowledge creation maps, knowledge assessment or audit maps, knowledge identification maps, etc.
2. by content, which is represented in the map (‘‘what?’’): by content format (blogs, books, repositories, online courses, etc.) and content type (methods, experts, processes, departments, lessons learned, etc.
3. by graphic form for representing the map (‘‘how?’’): includes all spectrum of visuals from matrixes to metaphors
4. by their creation method (‘‘how?’’ and ‘‘who?’’) - from community-generated maps that are constantly revised by map users to automatically generated maps;
5. by the level at which the map is applied (‘‘who?’’): personal, dyadic, team, departmental, community, organizational, and inter-organizational levels in the enterprise.

APQC classification focuses on the organizational level and distinguishes enterprise, process- and role-based levels for knowledge map application [11]. APQC classification of knowledge maps focuses on the organizational level and distinguishes enterprise, cross-functional, process- and role-based levels for knowledge map application. At the enterprise level APQC recommends focusing on the fit between strategic goals and organizational knowledge using Strategic Overview Map and on knowledge at risk in Expertise Overview Map. At the next level, cross-functional, the maps help to identify knowledge

(Expertise tacit map) and to understand potentials and gaps (Technical/Functional knowledge map). Lastly, at the process- and role-level APQC suggests identifying needs and sources of knowledge via Process-based map and Job/Role-based map. Another type of knowledge map at this level is Competency/Learning needs map. As the title implies, this map outlines the learning needs associated with a business process or job role.

These typologies [7, 8, 10, 11] provided a sufficient and representative amount of knowledge map types for further analysis. Descriptions of these types were used for the analysis of their content.

The major part of these maps is presenting practical KM applications [12].

2.2. Ontology-based knowledge maps

Ontological analysis within the knowledge mapping context was used by a set of researchers [13, 14]. They integrated knowledge maps with process maps in health care via ontology engineering and applied the who-what-why categorization of knowledge map instances together with the organizational ontology for process reengineering. In both cases, the authors have chosen a certain set of knowledge maps that match their main research purpose and didn't provide an overview of existing knowledge mapping templates. While the practical usefulness of ontological decomposition of knowledge maps was demonstrated, research was still needed to study a variety of knowledge maps in use.

2.3. Knowledge modeling from an enterprise modeling perspective

There are also a lot of frameworks for modeling knowledge, which were suggested within the enterprise modeling community. These frameworks and methodologies are compared in [15] and can be divided into business process-oriented approaches, knowledge work-oriented approaches, agent-oriented approaches, and holistic approaches. Typical objects for knowledge modeling within the enterprise modeling research: knowledge and its status, organizational processes, types of knowledge flows, and knowledge management enablers. Such a research stream may complement the current paper but does not clarify the meaning of knowledge mapping.

3. Research methodology

Our research methodology is based on literature review, semantic analysis, and ontological engineering. Existing typologies, templates, and examples of organizational knowledge maps from literature are analyzed using semantic analysis – the main concepts, which are represented in knowledge maps, and relationships between them are extracted. Methods of ontology engineering are used for establishing a unifying ontology (conceptual model) for knowledge maps.

The research process is presented in Fig. 1.

The research started with a literature review, which was focused on the analysis of existing typologies of knowledge maps (Section 2). This analysis helped to select knowledge map examples and templates for further specification. The literature review was the main method at this step.

This analysis provided input information for ontology development (Section 4), which combined ontology requirements specification via competency questions [16] with pattern-based ontology design [17]. Knowledge map typologies provided the basis for competency questions (Section 4.1), while the selected examples and templates were used for creating the associated information models, which were used as content ontology patterns (Section 4.2). These competency questions and content patterns helped to suggest ontology (Section 4.3). The paper also provides the guidelines for knowledge mapping ontology application and demonstrates them via a case study – see Section 5.

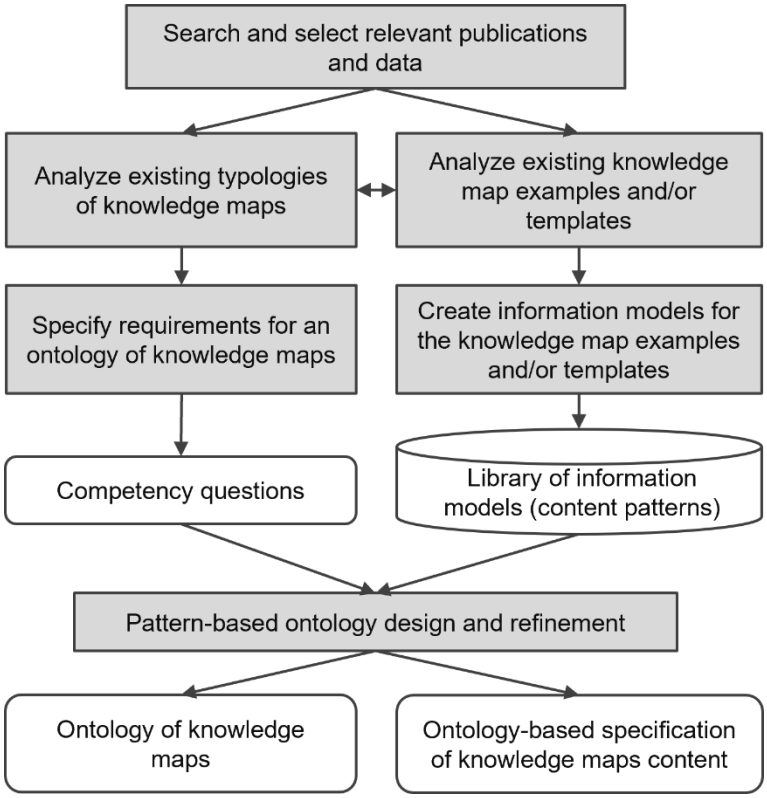


Figure 1. The research process of the study

4. Knowledge maps ontology development

4.1. Competency questions

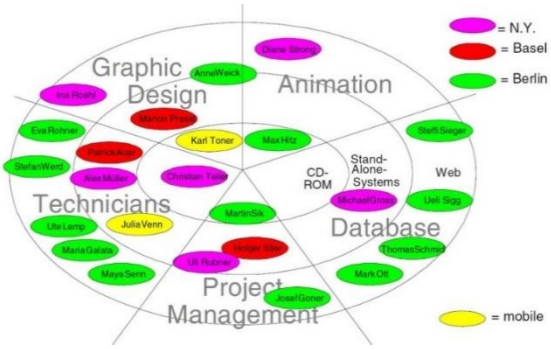
The analysis of different types of knowledge maps helped specify questions that may be answered using knowledge maps. These questions can be considered competency questions, which define functional requirements for ontology engineering:

1. What kind of knowledge does a company have?
2. Where is knowledge used and what knowledge is needed?
3. What are the sources of knowledge?
4. How can knowledge be assessed?
5. How is knowledge exchanged?
6. How is knowledge created/acquired/developed?

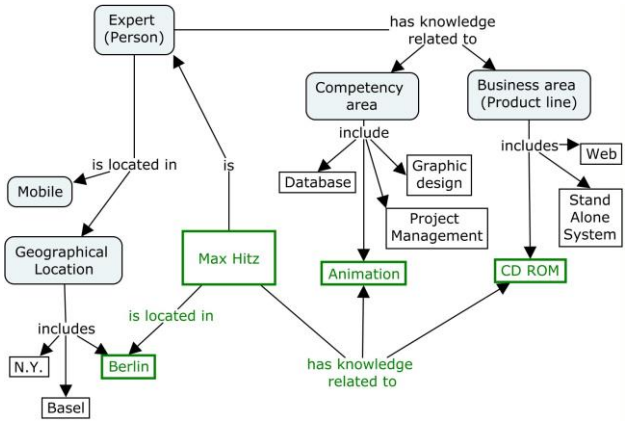
4.2. Information models of knowledge maps content

Specifications of content for the selected knowledge map examples and templates – information models – can be considered as content ontology design patterns ("content patterns") for creating an ontology of knowledge maps. Fig. 2 demonstrates an example of the information model, which specifies the content categories of the knowledge source map. The exemplary map (Fig. 2a) has several categories: role, location, and competency area. The interrelations between those categories as well as an example for one person are presented in Fig.2 b.

Fig. 2 represents a building block of an ontology of knowledge maps. High-level groups of concepts are aligned with competency questions. Similar information models were developed for other types of maps mentioned in Section 2.1; after that the pattern-based ontology design was applied to unite them.



a: Example of knowledge source map [7]



b: Information model for the knowledge source map (created by authors)

Figure 2. Creation of information models for knowledge map examples

4.3. Knowledge maps ontology

According to Presutti [17] the idea of pattern-based design implies that "the ontology project is divided into the problem and solution spaces. The problem space contains a set of requirements (see Competency questions), while the solution space contains a set of ontology-design patterns. The two spaces are compared in order to identify patterns matching the requirements." Then relevant patterns are selected and combined.

Figure 3 generalizes the above-described information models of different knowledge maps (content ontology patterns) into a cohesive ontology. The ontology represents four broad areas: knowledge itself, its application, sources, and assessment. Each of the above-mentioned areas gives answers to one of the general competency questions: what kind of knowledge does a company have; where is it located; etc. A detailed set of notions and relations is given inside each of them. A list of synonymous verbs is given for some types of relations (e.g. between Knowledge and Knowledge Sources).

This ontology gives a broader and deeper understanding of knowledge map content and design. More specifically, the ontology can be used for defining the content of existing knowledge maps – based on the presented ontology the overlaps of concepts were identified and reflected in Table 1. This ontology-based specification of knowledge maps can be considered as a navigator which helps to identify relevant knowledge mapping templates for describing certain content or to support the analysis of existing knowledge mapping templates.

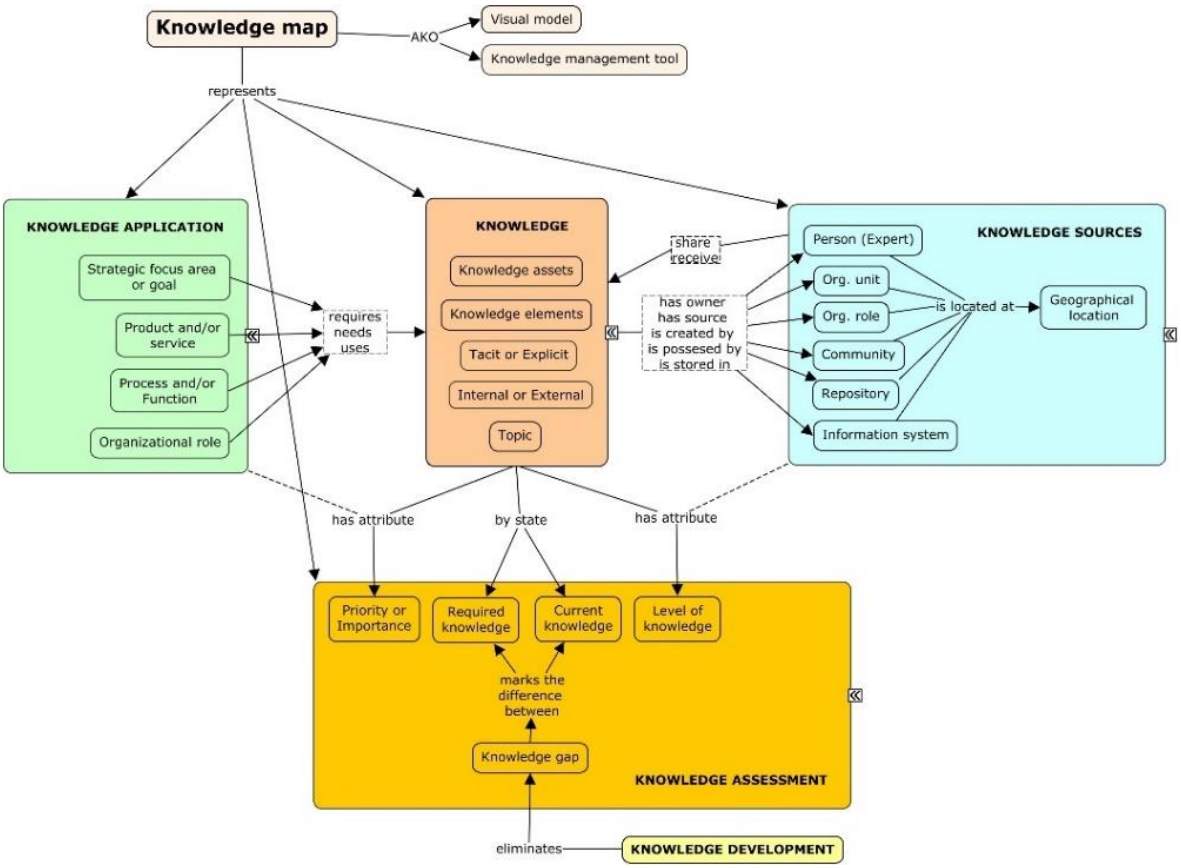


Figure 3. Informal knowledge maps ontology

This ontology was further represented in the ontology editor – see fig. 4 and 5.

Figure 4. Taxonomy of classes in the knowledge maps ontology

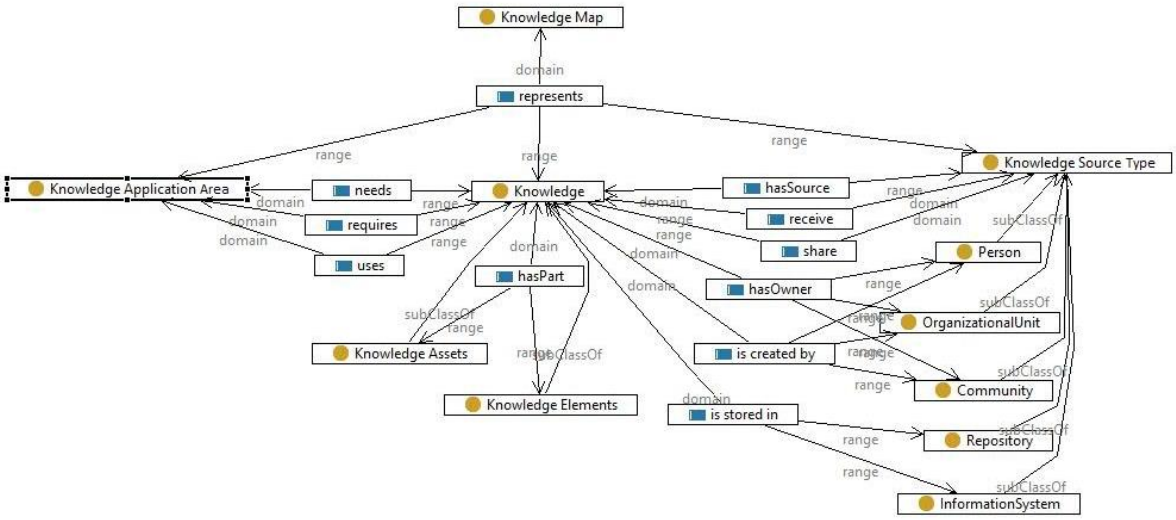


Figure 5. A fragment of relationships between classes in the knowledge maps ontology

Table 1

Ontology-based specification of knowledge maps content (fragment)

Concepts of the knowledge map ontology / Knowledge mapping templates	Knowledge structure map [7]	Knowledge source map [7]	Knowledge application map [7]	Knowledge-assets map [7]	Knowledge-assessment or audit map [8]	Knowledge-identification map [8]	Cross-functional Knowledge map [11]	Strategic overview knowledge map [10]	Process-Based Knowledge map [10]	Job / role based map [10]
Knowledge (assets, elements)	+	+	+	+	+	+	+	+	+	+
Tacit or Explicit	+						+		+	
Knowledge source types		+		+	+	+	+	+	+	
Repository						+		+		
Information system		+				+				
Person (Expert)		+		+		+				
Organizational Role							+		+	
Community								+		
Organizational unit				+			+		+	
Geographical location		+				+				
Knowledge application area		+	+					+		+
Strategic focus area or goal								+		
Product and/or Service		+					+			
Process and/or Function		+	+				+		+	
Organizational Role										+
Knowledge assessment				+	+			+	+	
Priority or Importance					+			+		
Level of expertise				+			+			
Required (needed) knowledge								+	+	
Current knowledge								+		
Knowledge gap								+	+	

5. Knowledge maps ontology application

5.1. Approach for the knowledge maps ontology application

We propose the following knowledge maps design process for companies, which is based on the suggested ontology, competency questions, and the table with knowledge maps specifications:

1. Define the goals/purpose of the knowledge map application
2. Select relevant competency questions from the list in section 4.1
3. Identify the necessary ontology elements – see section 4.3
4. Identify possible knowledge map types and templates for reuse via table 1
5. Design company-specific knowledge map template/-s

5.2. Example of the knowledge maps ontology application

Our team has applied the above-described approach in several knowledge-intensive organizations. The main challenge that we faced in knowledge mapping was the absence of knowledge domain structure. One of the cases is described further in more detail as it follows step by step the suggested methodology.

1. **Purpose** was stated by the company manager in a broad way: to identify and evaluate existing knowledge assets in one subdivision. That subdivision comprises more than 300 people distributed in eight cities and working in four different subject areas.
2. **Competency questions** were chosen from four abovementioned groups as follows:

    a) What kind of knowledge does a company have?
    b) What are the sources of knowledge?
    c) Where is knowledge used and what knowledge is needed?
    d) How can knowledge be assessed?

    Moreover, to identify knowledge exchange auxiliary question was introduced:
3. **Ontology elements**. A broad set of ontology elements from Table 1 was mapped:

    a) Knowledge
    b) Knowledge sources: Person and Role
    c) Knowledge application: Process and/or Function, Product and/or Service
    d) Knowledge assessment: Level of expertise /Current knowledge

4. **Templates for reuse**. According to Table 1, three main templates were chosen for reuse and adaptation:

    Knowledge source map, Knowledge assets map and Process-based knowledge map

5. **Company-specific knowledge maps.** The large questionnaire produced rich data for the mapping. It was represented in a bundle of interactive knowledge maps rather than one static picture. That bundle includes but is not limited to the maps described further.

Table 2. Roles and knowledge domains map

			Knowledge domain			
Department	Role	Name	Digital technologies	Sedimentology	Petro-physics	Explorative geology
Data analysis	Specialist of petrophysics	Anna			5	
	Lab worker	Viktor	4		2	1
	Expert	Olga	5	5		
	Specialist of 3D modelling	Andrew	5		2	3

The second view, the "Process resource map" (see table 3) is a managerial tool for strategizing and project planning. It represents the number of knowledge owners and their level of expertise.

Table 3. Process resource map

Process	Actions	#of knowledge owners	Anna	Viktor	…	Olga	Andrew
Seismic data interpretation	Data quality control	2		4			1
	Structural data interpretation	5				5	5
	Dynamic data interpretation	7		2		5	5
	Calculation of geological uncertainties	11	4			5	3

6. Conclusion

Professional knowledge maps help to identify intellectual capital, socialize new members, enhance organizational learning, and help anticipate impending threats and opportunities [6]. Knowledge mapping makes feasible the process of continuously evolving organizational memory, capturing and integrating strategic explicit knowledge [18]. This process takes place within a company or institution and between it and its external environment [18]. Knowledge mapping may also support the learning within the company as it enhances and enriches the visibility of knowledge structure.

This paper and designed ontology clarify the theory and practical content of knowledge maps, their meaning, and possible components. It provides building blocks for creating company-specific knowledge mapping templates and practices. In the context of the digital era, the created ontology may improve the design of an information system and integration of this system into overall organizational IT architecture [18, 19].

The presented ontology of knowledge maps can be used as an approach to develop an IT solution for automating the knowledge map building and application using knowledge graphs [20]. The knowledge map becomes a map of the maps by integrating the knowledge sources, patterns, applications, and locations into one "big picture" combining and projecting different company business maps.

7. Acknowledgements

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