VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Inga BELEVIČIŪTĖ

A SYSTEM ARCHITECTURE CENTRED ON KNOWLEDGE MANAGEMENT PROCESSES

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Technological Sciences, Informatics Engineering – 07T

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Abstract

The thesis “A system architecture centred on knowledge management processes” consists of these chapters:

1. Introduction.
2. Knowledge management and knowledge management tools.
3. Analysis of knowledge management systems, their architectures and solutions.
4. A system architecture centred on knowledge management processes.
5. Knowledge management implementations in organizations.
6. General conclusions.

The introduction chapter covers relevance, tasks, object, scientific novelty and practical value of the research, and work approbation in international conferences.

The first chapter presents knowledge management definitions discussed by many authors in academia and industry. To enter into this subject, knowledge determinations and interpretations widely discussed in literature are analysed. Later, tasks which knowledge management solves in organizations and tools which help to put it into practice are discussed.

In the second chapter architectures of knowledge management systems suggested by other researchers in literature are investigated. Thereafter, a classification of them and an investigation of examples of such systems or solutions are made.

After the analysis of knowledge management discipline and existing knowledge management system architectures, an architecture for knowledge management systems which is knowledge management processes centred is suggested in the third chapter. Then, specifications of information and communication technologies which could be used for each knowledge management process are made using unified modelling language (UML) diagrams.

In the fourth chapter the suggested architecture of knowledge management systems and modelled processes in UML diagrams are tested in three different environments: technology enhanced learning, public sector and project management area.

The thesis comes to an end with general conclusions about accomplished research and reached goals

Reziumė

Disertaciją Sistemos architektūra, grindžiamos žinių valdymo procesais sudaro šie skyriai:

1. Įvadas.
2. Žinių valdymas bei žinių valdymo technologijos.
3. Žinių valdymo sistemų ir jų architektūrų analizė.
4. Sistemos architektūra, grindžiamos žinių valdymo procesais.
5. Žinių valdymo sistemos taikymas organizacijose.
6. Bendrosios išvados.

Įvadas apima tyrimo aktualumą, mokslinį naujumą, darbo tikslus ir uždavinius, praktinę tyrimo vertę bei aprobavimą tarptautinėse konferencijose ir seminaruose.

Pirmame skyriuje „Žinių valdymas ir žinių valdymo technologijos“ pateikiamas žinių valdymo sąvokos apibrėžimas, apie kurį diskutuoja daugelis autorių, dirbančių mokslo ir pramonės srityse. Žinių valdymas pradedamas nagrinėti nuo žinių apibrėžimo ir jo interpretavimo, plačiai aptariamo literatūroje. Tuomet pereinama prie priemonių, padedančių įdiegti žinių valdymą praktikoje.

Antrame skyriuje „Žinių valdymo sistemų ir jų architektūrų analizė“ analizuojamos kitų tyrėjų veikaluose siūlomos žinių valdymo sistemų architektūros. Klasifikuojami ir tiriami tokių sistemų arba sprendimų pavyzdžiai, suskirstant juos į komercinius ir atvirojo kodo šaltinius.

Išanalizavus egzistuojančias žinių valdymo sistemų architektūras, trečiame skyriuje „Sistemos architektūra, grindžiamos žinių valdymo procesais“ siūloma žinių valdymo sistemos architektūra, sutelkta į žinių valdymo procesus. Tuomet apibūdinamos informacinės ir komunikacinės technologijos, kurias galima taikyti kiekvienam žinių valdymo procesui, naudojant unifikuotos modeliavimo kalbos (UML) diagramas.

Ketvirtame skyriuje „Žinių valdymo sistemos taikymas organizacijose“ siūloma žinių valdymo sistemos architektūra ir UML diagramose sumodeliuoti procesai išbandomi trijose skirtingose aplinkose: viešojo sektoriaus, projektų valdymo srityje ir technologijomis grindžiamame mokyme.

Darbas baigiamas bendromis išvadomis apie atliktą tyrimą ir pasiektus tikslus.

Notations

Abbreviations

Term	Definition
ADIPS	Agent-based distributed information processing system
ADL	Advanced distributed learning
AT	Authoring tool
CMS	Content management system
DB	Data base
DM	Data mining
DMS	Document management system
EKP	Enterprise knowledge pattern
ERP	Enterprise resource planning
ICT	Information and communication technologies
IS	Information system
IT	Information technologies
KB	Knowledge base
KBS	Knowledge base system
KE	Knowledge engineering
KM	Knowledge management
KMP	Knowledge management processes
KMS	Knowledge management system
KP	Knowledge portal
LD	Learning design
LDAP	Lightweight directory access protocol
LDS	Lotus Discovery system
LMS	Learning management system
LO	Learning object
OLAP	Online analytical processing
PPS	Project planning system
SCORM	Sharable content object reference model
SECI	Socialization, externalization, combination,

	internalization
SOA	Service oriented architecture
TEL	Technology enhanced learning
UDDI	Universal description, discovery and integration
UML	Unified modelling language
WfMS	Workflow management system
XML	Extensible markup language

Glossary

Term	Definition
Knowledge	Experience, values, insights, and contextual information [22].
Explicit knowledge	Articulated and codified knowledge. Examples are manuals, documents, instructions, video, audio, etc.
Implicit knowledge	Knowledge which can be articulated but is not yet.
Tacit knowledge	Knowledge which cannot be codified.
Knowledge management	Collection of processes that govern knowledge creation, transfer, applying storage/retrieval [3].
Knowledge engineering	Part of artificial intelligence discipline and focuses on the development of formalisms, inference mechanisms and tools to operationalize knowledge-based systems [45], [99].
Knowledge management system	Information and communication technologies platform that combines and integrates functions for the contextualized handling of both, explicit and implicit knowledge [56].
System architecture	Integrated structural design of a system, it's elements and their relationships depending on given system requirements [10].
Knowledge creation	Explicit and implicit knowledge conversion [76].
Knowledge transferring	Distributing knowledge to locations where is needed and used [3].
Knowledge applying	Ability of utilizing knowledge to confront the new situations in organization [3].
Knowledge storage/retrieval	Retention/accessibility of knowledge assets in organization [3].

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Introduction

Relevance and problem of the research

The strategic goal for 2010 set for Europe at the Lisbon European Council is to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion [98].

Importance of knowledge to organizations as one of the intellectual assets is growing together with the knowledge economy. Organizations that want to achieve an enterprise's effectiveness and competitiveness are dealing with knowledge management [52]. Knowledge workers gain more and more influence in organizations because businesses focus on knowledge and their holders as key competitive factors. Knowledge workers are increasingly supported by information and communication technologies as cost and time effective ways to enable these goals [56].

Knowledge management integrates in existing management disciplines like human resource management, business intelligence, strategic management, etc. However, as already stated by Woitsch and Karagiannis in [109]: "Current status is [therefore] a tight coupling on the technical layer but a rather loose and weak integration at the management layer." An analysis of existing knowledge management system architectures [1], [9], [55], [90], [6], [26], [18] verifies the statement as well. Several explanations for this phenomenon can be found in literature. It is argued that because KM is used to improve efficiency, and computers are generally more efficient in information processing, people tend to concentrate on technology. Others explain the technical focus of KM with its roots in artificial intelligence. As a result, the challenge of today's research is to integrate knowledge management not only at the technical but also on the management layer [109].

Some years ago knowledge management was a prerogative of large enterprises. Critical success factors for implementing knowledge management in small and medium enterprises have not been systematically investigated. Existing studies have derived their success factors from large companies' perspectives and have not considered the needs of smaller businesses [110]. However, in our days, small and especially medium-sized companies need to manage their knowledge as well to keep the competitive edge. Unfortunately, current architectures are often too complex or all-encompassing for smaller companies with limited resources and know-how. Consequently, KM architectures and systems have to be adapted to meet the requirements of those enterprises.

In order to improve KM initiatives and link them to management and business strategy, we suggest a process centred knowledge management approach i.e. a knowledge management system architecture which is layered and knowledge management processes oriented aiming at a better integration at the management level and suitable for small and medium businesses as well.

Aim of the research

The aim of the research is to create an architecture that integrates knowledge management processes into knowledge management systems to bridge the gap between management and technology oriented KM.

Tasks of the research

The tasks of research are:

1. To analyze the current state of knowledge management.
2. To analyze information and communication technologies used for knowledge management and KMS architectures from KMP point of view.
3. To conceive a KMP centred architecture for knowledge management systems.
4. To conceptualize information and communication technologies for each of the knowledge management processes in UML (unified modelling language).
5. To implement the suggested architecture for different types of projects: technology enhanced learning, project management and public sectors.

Scientific novelty

The power of information and communication technologies for knowledge management is widely recognized. Most of current knowledge management systems do not excerpt a knowledge management process level. Some of them are centred to business or learning processes, but take knowledge management theories and processes poorly into account – sometimes even not at all.

In this thesis a knowledge management processes centred knowledge management system architecture is suggested. Every process is supported by different kinds of technologies and all of these technologies are integrated into the system.

Practical value

The suggested knowledge management system architecture was implemented in the education field (university), the public sector (the Ministry of Finance of the Republic of Lithuania) and the business area (joint stock company ERP) considering realistic organization constraints and rules.

Practical implementations of KMS architecture confirmed suitability and adaptability of the system for small and medium organizations and projects.

Presented for defence

1. Knowledge management system architecture which is centred to knowledge management processes.
2. Specification of information and communication technologies for knowledge management processes: knowledge creation, knowledge storage/retrieval, knowledge transferring, knowledge applying.

Methodology of the research

Methodology of research includes a comparative analysis of scientific literature, research generalisation and logical induction methods to analyze knowledge management, knowledge management technologies and KMS architectures. Experimental research methods were applied to implement the knowledge management system architecture.

Approbations

The author has published with co-authors two papers in journals included in Thomson ISI Web of Science, two papers in the Lithuanian journals that meet the requirements of Lithuanian Council of Science for the publications obligatory for defence of doctoral dissertation, one paper in Thomson ISI Proceedings, and three papers in international reviewed conferences proceedings. The author has presented her research in conferences and workshops:

1. XLIV conference of Lithuanian mathematical society, Kaunas, 2004.
2. Workshop of Wireless Information Management on Strategies for the Mobile Internet, Jyvaskyla University, Finland, 2004.
3. International Conference on Naukovij potencial miru СВIТУ' Marketing and management, Belgorod-Dnepropetrovsk-Praha, 2004.
4. International conference on Knowledge society challenges for e-learning, Kaunas, 2005.
5. PhD students workshop, PROLEARN (technology enhanced learning) summer school, Bled, Slovenia, 2006.
6. 3rd WSEAS/IASME International Conference on Engineering Education, Greece, July 2006.
7. PhD students workshop, PROLEARN (technology enhanced learning) summer school, Frejus, France, 2007.
8. 6th WSEAS International Conference on Applications of Electrical Engineering, Istanbul, Turkey, May 2007.
9. 7th International Conference on Knowledge Management, I-KNOW'07, Graz, Austria, 2007.

1

Knowledge management and knowledge management tools

In this chapter knowledge management definitions discussed by many authors in academia and industry are presented (1.2. Knowledge management overview). To enter into this subject, knowledge is determined and its interpretations widely discussed in literature (1.1. Knowledge definitions) are presented. Later, tasks which knowledge management solves in organizations and tools which help to put it into practice are analyzed (1.3. Tasks to be solved by knowledge management).

1.1. Knowledge definitions

Before talking about knowledge management it is better to start from knowledge. Determination of knowledge started in Greeks era. Western philosophers have generally agreed that knowledge is justified true belief. In IT literature many authors define knowledge by distinguishing data, information, knowledge and wisdom [41], [84], [2].

Data occurs through research, creation, gathering, and discovery. Information has context. Data is turned into information by organizing it so that we can easily draw conclusions. Knowledge has the complexity of experience, which comes about by seeing it from different perspectives. This is why training and education is difficult – one cannot count on one person's knowledge transferring to another. Knowledge is built from scratch by the learner through experience. Information is static, but knowledge is dynamic as it lives within us. Wisdom is the ultimate level of understanding. As with knowledge, wisdom operates within us. We can share our experiences that create the building blocks for wisdom; however, it needs to be communicated with even more understanding of the personal contexts of our audience than with knowledge sharing [17].

Data and information deal with the past. They are based on the gathering of facts and adding context. Knowledge deals with the present. It becomes a part of us and enables to act. However, when we gain wisdom, we start dealing with the future as we are now able to vision and design for what will be, rather than for what is or was [22].

Often, the distinctions between the data, information, knowledge, and wisdom continuum are not very discrete, thus the distinctions between each term often seem more like shades of gray, rather than black and white [91]. What represents knowledge or information to one person may be data to another person.

Knowledge consists of efficient fantasies. Each fantasy has a context, a purpose and a target group, and it is only when you have decided how you are going to evaluate the efficiency of your fantasies – within this context, for this purpose, and against this target group – that you can speak about “validation of knowledge” [70], [124].

Stenmark has summarized knowledge definitions by many authors shown in Table 1 [97].

Table 1. Knowledge definition by different authors

Author(s), years	**Data**	**Information**	**Knowledge**
Wiig, 1993 [106]	–	Facts organized to describe a situation or condition	Truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how
Nonaka and Takeuchi, 1995 [76]	–	A flow of meaningful messages	Commitments and beliefs created from these messages
Spek and Spijkerveret, 1997 [95]	Not yet interpreted symbols	Data with meaning	The ability to assign meaning
Davenport, 1997 [22]	Simple observations	Data with relevance and purpose	Valuable information from human mind

End of Table 1

Author(s), years	Data	Information	Knowledge
Davenport and Prusak, 1998 [21]	A set of discrete facts	A message meant to change the receiver's perception	Experience, values, insights, and contextual information
Quigley and Debons, 1999 [82]	Text that does not answer to a particular problem	Text that answers the question who, when, what or where	Text that answers the questions why or how
Choo, Detlor, Tumbull, 2000 [3]	Facts and messages	Data vested with meaning	Justified, true, beliefs

Polanyi divided knowledge into explicit and tacit [81], [80]. Tacit knowledge is personal, context-specific, and therefore hard to formalize and communicate. Explicit or codified knowledge, on the other hand, refers to knowledge that is transmittable in a formal, systematic language [76], [104].

Later on, a differentiation between tacit and implicit knowledge was made. Implicit knowledge can be articulated but is not yet, and tacit cannot be articulated at all. As Polanyi wrote that we know more than we can tell [79].

Alavi and Leidner have classified knowledge taxonomies [3] (Table 2).

Table 2. Knowledge taxonomies and their examples

Knowledge types	Definitions	Examples
Tacit	Knowledge is rooted in actions, experience, and involvement in specific context	Best means of dealing with specific customer
Cognitive tacit:	Mental models	Individual's belief on cause effect relationships
Technical tacit:	Know-how applicable to specific work	Surgery skills

End of table 2

Knowledge types	Definitions	Examples
Explicit	Articulated, generalized knowledge	Knowledge of major customers in a region
Individual	Created by and inherent in the individual	Insights gained from completed project
Social	Created by and inherent in collective actions of a group	Norms for inter-group communication
Declarative	Know-about	What drug is appropriate for an illness
Procedural	Know-how	How to administer a particular drug
Causal	Know-why	Understanding why the drug works
Conditional	Know-when	Understanding when to prescribe the drug
Relational	Know-with	Understanding how the drug interacts with other drugs
Pragmatic	Useful knowledge for an organization	Best practices, business frameworks, project experiences, engineering drawings, market reports

Ambjörn Naeve has created knowledge prefix (Figure 21. Knowledge prefix ontology) and postfix ontology (Figure 22. Knowledge postfix ontology [124]) using Conzilla, a conceptual browser [124]. These ontologies are available online to everyone by connecting to the address mentioned in the footnotes in Figure 22 and Figure 21 and downloading Conzilla from www.conzilla.org or [124] (see Appendixes).

In Figure 22 he describes possible knowledge postfixes like knowledge discovery, knowledge base, knowledge architecture, knowledge management, knowledge sharing, etc. by putting links between different conceptions. A rectangle means concept, a line with an arrow at the end – "kind of", a line with a diamond at the end – "has", a dashed line with an arrow – "is a", a direct line – "association", and a direct line with an arrow at the end – "directed-association". For example the concepts knowledge sharing, dissemination, creation, capture, acquisition, application are directly associated and also have a cycle. The cycle has management and management – knowledge.

Figure 21 shows the knowledge prefix ontology. It contains prefixes like organizational knowledge, metaknowledge, media knowledge, etc. For example the concept of organizational has codified, explicit, tacit, and implicit which are all a kind of knowledge. Furthermore, organizational itself is also a kind of knowledge.

An absolutely different point of view to knowledge has Tuomi. He argues that the often-assumed hierarchy from data to knowledge is actually inverse: knowledge must exist before information can be formulated and before data can be measured to form information [102]. As such, raw data does not exist. Even the most elementary piece of data has already been influenced by the thought or knowledge processes that led to its identification and collection. Knowledge exists which, when articulated, verbalized, and structured, becomes information which, when assigned a fixed representation and standard interpretation, becomes data [93]. Wilson claims that knowledge can exist only in people's minds and by expressing ourselves we convert it to information and the term of knowledge management is "nonsense" [107].

1.2. Knowledge management overview

The field of knowledge management (KM) struggles with a large number of terms that are used differently, approaches that are incommensurable and lack applicability in a business context [57].

Despite many interpretations of knowledge and even claims that knowledge management is "nonsense" [107] and nothing more than information management, there is a difference between knowledge management and information management. Working with objects (data or information) is information management and working with people is knowledge management. Creation, use, learning, meaning, understanding, and negotiation are not core issues, but efficiency, timeliness, accuracy, veracity, speed, cost, storage space and retrieval are central concerns in information management [36].

Knowledge management may be viewed from each of the following perspectives 0:

- techno-centric: a focus on technology, ideally those that enhance knowledge sharing/growth,
- organisational: how does the organisation need to be designed to facilitate knowledge processes? Which organisations work best with what processes?

- ecological: seeing the interaction of people, identity, knowledge and environmental factors as a complex adaptive system.

In the thesis knowledge management from a techno-centric point of view is analyzed.

Very often the terms of knowledge management and knowledge engineering are entwined in literature. Knowledge engineering is a part of artificial intelligence discipline and focuses on the development of formalisms, inference mechanisms and tools to operationalize knowledge-based systems [45], [99], [87] while knowledge management primarily is subject of management. KM is the art of performing knowledge actions such as organizing, blocking, filtering, storing, gathering, sharing, disseminating, and using knowledge objects such as data, information, experiences, evaluations, insights, wisdom and initiatives — all of which, though not identical, are, from the point of view of KM, simply items to be managed [93].

In general terms, KM is the performance of knowledge actions on knowledge objects: KM = KA x KO, where KA – knowledge actions (organizing, storing, gathering, sharing, disseminating, using…), KO – knowledge objects (data, information, experience, evaluations, insights, wisdom, initiatives…) [93].

Seeley and Dietrick write that building a knowledge management strategy should use the following components:

- governance,
- culture,
- content management,
- technology,
- application and measurement [89].

Nonaka and Takeuchi argued that a successful KM program needs, on the one hand, to convert internalized tacit knowledge into explicit codified knowledge in order to share it, but also on the other hand for individuals and groups to internalize and make the codified knowledge personally meaningful once it is retrieved from the KM system [76]. The main focus they made is on knowledge creation which occurs during explicit and tacit knowledge conversion (Table 3) and takes four stages, the so-called SECI spiral [76]:

- socialization is a process of sharing experiences and thereby creating tacit knowledge such as shared mental models and technical skills,
- externalization is a process of articulating tacit knowledge into explicit concepts. It is a quintessential knowledge creation process in that tacit knowledge becomes explicit, taking the shapes of metaphors, analogies, concepts, hypothesis, or models,

- combination is a process of systemizing concepts into a knowledge system. This mode of knowledge conversion involves combining different bodies of explicit knowledge. Reconfiguration of existing information through sorting, adding, combining, and categorizing of explicit knowledge can lead to new knowledge,
- internalization is a process of embodying explicit knowledge into tacit knowledge. It is closely related to learning by doing. When experiences thought socialization, externalization, and combination are internalized into individuals' tacit knowledge bases in the form of shared mental models or technical know-how, they become valuable assets.

Table 3. Conversion of tacit and explicit knowledge by Nonaka

Type of knowledge	**Tacit**	**Explicit**
Tacit to	Socialization	Externalization
Explicit to	Internalization	Combination

Naeve at al. have combined learning process modelling with the SECI theory of knowledge creation and created a SECI process framework (abstract model) for the description and classification of knowledge creating learning processes. In each of the four SECI knowledge conversion stages a learning process takes place [74].

Learning and knowledge management are increasingly similar in terms of input, outcome, processes, activities, components, tools, concepts, and terminologies and can thus be viewed as two sides of the same coin [16].

In Figure 23 (see Appendixes) the different knowledge conversions have been modelled as processes. During the socialization process we respond to challenges and activities by collecting inspiring experiences. During the externalization process they form the input for discussions, which produce articulated concepts. During the combination process, these articulated concepts are connected and combined into conceptual models, and during the internalization process, these conceptual models are reflected upon, which results in increased understanding of the issues involved [74].

Teece looks at knowledge management as an umbrella to integrate work in accounting, economics, entrepreneurship, organization behaviour, marketing, sociology, and strategy [100].

Schmitz and Zucker at all suggested renaming management *of* knowledge to management *for* knowledge emphasizing that many KM approaches look to knowledge as an object [88].

Mentzas, Apostolou, Abecker, Young excerpt one of two KM approaches: the process-centric approach, which mainly treats KM as social communication process; and the product-centric approach, which focuses on knowledge artefacts, their creation, storage and reuse in computer-based corporate memories [65].

Maier and Remus stress the gap between human and technology oriented KM. In order to improve these KM initiatives and link them to business strategy, they suggest a process-oriented knowledge management approach [59].

Woitsch and Karagiannis point out that current knowledge management is a tight coupling on the technical layer but a rather loose and weak integration at the management layer [109]. To solve that problem they also suggest a process orientated KM.

Alavi and Leidner described knowledge management as KM lifecycle which consist of four basic processes:

- knowledge creation,
- knowledge storing/retrieving,
- knowledge transferring,
- applying knowledge [3].

Knowledge creation refers to the creativity of an organization to develop novel and useful ideas and solutions, for instance, creating new products, new ideas, more efficient processes and new skills [11], [76]. Knowledge storage/retrieval refers to the retention/accessibility of knowledge assets in organization, namely organizational memory. That is the knowledge residing in various component forms, including written documentation, structured information stored in electronic databases, codified human knowledge in expert systems, documented organizational procedures and processes and implicit knowledge acquired by individuals and networks of individuals [3]. Knowledge transfer refers to the availability of knowledge throughout the organization, which means distributing knowledge to locations where it is needed and used [3]. Knowledge application refers to the ability of utilizing knowledge to confront new situations in an organization. The source of competitive advantage for an organization resides in the application of knowledge rather than the knowledge itself [3].

Some other authors like Liebowitz divided knowledge management into nine processes: transform information into knowledge, identity and verify knowledge, capture and secure knowledge, organize knowledge, retrieve and apply knowledge, combine knowledge, create knowledge, learn knowledge, distribute/sell knowledge [51]. Davenport and Prusak represent the organizational KM processes into seven steps: identification, acquisition, preparation, allocation, dissemination, usage, and maintenance of knowledge [21].

Most of these processes mentioned above either repeat or could be generalized to the four processes: creation, storing/retrieving, transferring, and applying.

1.3. Tasks to be solved by knowledge management

According to Davenport and Prusak, most knowledge management projects have one of three aims [21]:

- to make knowledge visible and show the role of knowledge in an organization, mainly through maps, yellow pages, and hypertext tools,
- to develop a knowledge-intensive culture by encouraging and aggregating behaviours such as knowledge sharing (as opposed to hoarding) and proactively seeking and offering knowledge,
- to build a knowledge infrastructure not only a technical system, but a web of connections among people given space, time, tools, and encouragement to interact and collaborate.

Lotus and IBM define knowledge management as a discipline to systematically leverage information and expertise to improve organizational responsiveness, innovation, competency, and efficiency [103].

Maier differentiates knowledge management from business goals. Knowledge management goals would be transparency of knowledge, improve documentation of knowledge, change culture, improve communication and cooperation, turn implicit into explicit, improve education, training and networking of newly recruited employees, improve personnel development, improve retention of knowledge, improve access to existing knowledge, improve acquisition of external knowledge, improve distribution of knowledge, improve management of innovation, reduce costs, sell knowledge [55]. When business goals from KM initiative are reduce costs, improve productivity, improve speed of innovation, develop new business fields and topics, reduce business risks, improve employee satisfaction and motivation, improve growth of the organization, improve product quality, improve customer satisfaction and/or service quality, improve scheduling, reduce throughput/ running time, improve meeting of deadlines [55].

Summing up, the main tasks of knowledge management in organizations are improve productivity, creativity and innovations, reduce costs, not reinvent the wheel, and get the right knowledge to the right person at the right time.

1.4. Analysis of tools for knowledge management

Scientific and practical literature suggests many tools which could be used to solve KM problems.

Knowledge management tools are technologies, broadly defined, which enhance and enable knowledge generation, codification, and transfer. True knowledge management tools are not data or information management tools. They could also handle data and information, the other types are not robust enough to truly facilitate knowledge management [85].

Gupta and Sharma [90] depict a range of technologies and disciplines used in KM (Table 4).

Table 4. Technologies for knowledge management

Technologies & Tools	**Description**
Expert systems	An expert system is regarded as the embodiment within a computer of a knowledge-based component from an expert skill in such a form that the system can offer intelligent advice or make an intelligent decision about a processing function. Expert systems are computer-based programs which are designed to record human expertise (knowledge) and then apply this knowledge to applications in a certain domain.
Document management systems	*Document management* systems originally were primarily concerned with providing online access to documents stored as bit-mapped images. Document management technology, already in widespread use in large, information-intensive companies, is likely to become an integral part of virtually every intranet in one form or another.
Geographic information systems	*Geographic information systems,* a term associated with knowledge management, are used as graphic tool for *knowledge mapping.* Known by the acronym GIS for short, the technology involves a digitized map, a powerful computer and software that permits the superimposition and manipulation of various kinds of demographic and corporate data on the map.
Help desk technology	*Help desk technology* is primarily concerned with routing requests for help from information

End of Table 4

Technologies & Tools	Description
	seeker to the right technical resolution person within an organization.
Intranets	*Intranets,* intra-corporation networks that use the Internet protocol standard, not only permit sharing of information, but they also view the organization's information (including structured resources like relational databases, as well as unstructured text) through Web browsers.
Concept mapping	*Concept mapping* seems to be rooted primarily in educational techniques for improving understanding and retention, and as an aid to writing. A concept map is a picture of the ideas or topics in the information and the ways these ideas or topics are related to each other. It is a visual summary that shows the structure of the material the writer will describe.
Semantic networks	*Semantic networks* are often closely associated with detailed analysis of texts and networks of ideas. One of the important ways they are distinguished from hypertext systems is their support of semantic typing of links. For example, the relationship between “murder” and “death” might be described as “is a cause of.” The inverse relationship might be expressed as “is caused by.” Semantic networks are a technique for representing knowledge.
Hypertext (an expanded semantic network)	*Hypertext,* known to most people these days by its implementation in the World Wide Web, is sometimes described as a semantic network with content at the nodes. But the content itself, the traditional document model, seems to be the driving organizational force, not the network of links. In most hypertext documents, the links are **not** semantically typed, although they are typed at times according to the medium of the object displayed by traversing the link.
Information modelling	*Information modelling* is concerned with precise specification of the meaning in a text and in making relationships of meaning explicit, often with the objective of rapid and accurate

End of Table 4

Technologies & Tools	Description
	development of new software applications for business requirements. Some of the essence of information modelling is expressed in the following definition: The process of eliciting requirements from domain experts, formulating a complete and precise specification understandable to both domain experts and developers, and refining it using existing (or possible) implementation mechanisms.
Conceptual indexes	*Conceptual indexes* (or back-of-the-book) are rarely discussed in the same breath as hypertext, conceptual maps, and semantic networks, perhaps because indexers themselves sometimes relish the aura of "black art" surrounding indexing, but the connection is fundamental. Conceptual indexes traditionally map key ideas and objects in a single work. An index is a structured sequence, resulting from a thorough and complete analysis of text, of synthesized access points to all the information contained in the text. The structured arrangement of the index enables users to locate information efficiently.
Metadata	*Metadata* is simply information added to a document (or a smaller unit of information) that makes it easier to access and re-use that content. It's also referred to as simply data about data. You will find metadata in many different forms, including key words in a software help system, the document profile information attached to documents in a document management system, and the classification information in a library card catalog.

Dfouni and Croteau have made a research with empirical support investigating what technologies are used to support KM initiatives. In order to reach a stable consensus among knowledge leaders, they have conducted a web-based Delphi survey. This research identified the top ten most important technologies used to support KM initiatives, based on a level of agreement reached among worldwide knowledge leaders:

- portals,
- information retrieval engines,

- e-mail,
- collaborative work tools,
- document management systems,
- yellow pages of expertise,
- knowledge maps,
- discussion boards,
- e-learning technologies,
- data mining tools [24].

Davenport and others state that one of the common instruments used to organize, collect and merge knowledge is the web portal [23]. Traditionally, this is composed of the following elements [8]:

- contribution processes which enable members to manage the knowledge portal,
- chats and discussion groups, used to satisfy the need of social interaction,
- content management tools (text miners, search engines, and so on), which are used to produce a shared view (either implicit – e.g. , clusters, neural nets – or explicit – e.g. , ontologies, taxonomies) of the entire collection of corporate documents,
- common formats (such as HTML, XML, PDF), used to overcome the syntactic heterogeneity of documents composed of different knowledge sources.

Bubenko, Persson and Stirna [14] created enterprise knowledge patterns (EKD) for the organizational knowledge cycle. The latter conists of knowledge creating and capturing, knowledge packing and storing, knowledge sharing and applying, and knowledge transforming and innovating. They adapted organizational patterns for KM processes and suggested methods for creating a corporate knowledge repository for each of these activities.

Another research made by Alavi and Leidner [4] shows that for 90% of the organization the primary means of displaying and distributing knowledge in organizations are browser tools. The other two most common tools are electronic mail and search/retrieval tools. Table 5 shows the most common technologies and their distribution.

Many authors put accents that in knowledge management the most important is the human side and too much is expected from technologies. It is argued that knowledge management is just about 35 percent technology and the rest is about culture, consciousness, governance. But on the other hand technologies provide cost-efficient and time-efficient ways to change an organization’s handling with knowledge routines. Ruggles suggests keeping a balance of 50 % people-oriented, 25 % process-oriented organizational measures and 25 % technological measures from the start of a KM initiative [86].

Table 5. Dispersion of technologies/tools for knowledge management

Technology	Percent
Browser	90
Electronic mail	84
Search/ Retrieval tools	73
Information repositories	52
WWW server	42
Agents/ Filters	36
External server services	31
Videoconferencing	23

Following that, Maier formulates a hypothesis that organizations with systematic knowledge management that has been established for at least one year are more likely to have installed KMS than organizations without systematic knowledge management [55].

1.5. Conclusions of the 1st chapter

The analysis of current research in the knowledge management field indicates that knowledge management mainly consist of the four processes described by Alavi and Leidner which are knowledge creation, knowledge transfer, knowledge storage/retrieval, knowledge application. Some other authors divided knowledge management into more processes, but most of them either repeat or could be generalized to the four processes. Knowledge creation was deeply analyzed by Nonaka and divided into four stages, the so-called SECI processes: socialization, externalization, combination and internalization. Later Naeve combined learning-process modelling with the SECI theory of knowledge creation.

Research made on KM tools shows that among the primary technologies are portals, intranet or browser. Also there are e-mail, collaborative tools, intelligence and document/information repositories in this list of technologies supporting knowledge management.

2

Analysis of knowledge management systems, their architectures and solutions

In this chapter architectures of knowledge management systems (KMS) suggested by other researchers in literature are analyzed (2.2. Architectures of knowledge management system). After their classification (2.3. Classification of knowledge management systems), an investigation of examples of such systems or solutions is made by dividing them into industry and open source (2.3. Classification of knowledge management systems).

2.1. Introduction

To start our investigation of knowledge management systems architectures, definitions of knowledge management system and system architecture are shortly introduced. Knowledge management systems refer to a class of information systems applied to managing organizational knowledge [3]. They are an ICT platform that combines and integrates functions for the contextualized handling of both, explicit and tacit knowledge, through the organization or that part of the organization that is targeted by a KM initiative [56]. KMS combine and integrate functions e.g. for the publication, organization, visualization, distribution, search and retrieval of explicit knowledge as well as identification of experts, communication and collaboration in order to support the handling of implicit knowledge [55].

An information system architecture is the integrated structural design of a system, its elements and their relationships depending on given system requirements [10]. Information system architectures represent the structure of software applications on an abstract level. Components are delimited parts of software systems. Examples are functions, procedures, abstract data objects, abstract data types or object classes [58].

There are many types of information system architectures like layered, centralized client-server, service-oriented, peer to peer, agent, etc. At the heart of information systems architecture is the notation of different layers of an information system, each of which has distinct responsibilities [33]. Examples of layered architectures are ISO/OSI, 2-tier, 3-tier architectures.

More about information systems architectures is written by Bernus, Mertins and Schmidt [10], Fowler [33], Zachman [112].

2.2. Architectures of knowledge management systems

Depending on the approach to knowledge management different authors suggest different architectures for KMS.

Applehans, Globe and Laugero [6] suggest a knowledge management system architecture of six layers being:

- information and knowledge sources layer, called repositories,
- transport layer, which corresponds to an intranet infrastructure, extended by collaboration and streaming media tools layer,
- application layer, with the examples calendar, yellow pages and analysis tools,
- intelligence layer, which consist of search, personalization and agent technologies,
- access layer, that stresses security technologies,
- user interface layer, usually web browser.

The knowledge management system architecture suggested by Applehans et al. is shown in Figure 29 (see Appendixes).

Becker, Neumann and Serries present a KMS architecture from a metadata point of view [9]. They state that most organizations already have a number of systems that could be used for knowledge management functions. Becker and et al. conclude that KMS additions are basically restricted to the integration of application systems which are already installed in an organization with the help of a defined set of metadata and knowledge portal. The architecture is shown in Figure 30 (see Appendixes).

Maier uses the strongest points of existing systems and creates an “ideal” architecture for centralized knowledge management systems [56], [58]. He extracts six layers (Figure 31, see Appendixes):

- access layer,
- personalization services layer,
- knowledge services layer,
- integration services layer,
- infrastructure services layer,
- data and knowledge source layer.

On the access layer the participant or knowledge worker accesses the organization’s KMS with the help of a variety of access services. Personalization services are accessed by the knowledge workers through an enterprise, a work group, a project or a role specific knowledge portal respectively. The portal and the services can be personalized with the help of interest profiles, personal category nets and personalized portals. Knowledge services are search and retrieval, publication, collaboration and learning. These are key components of the KMS architecture and provide intelligent functions for publication, discovery, collaboration, and learning. Integration services are e.g. knowledge repository, which handles the organization’s metaknowledge describing knowledge elements that come from a variety of sources with the help of metadata for a number of dimensions like person, time, topic, location, process, type. Infrastructure services provide basic functionality for synchronous communication, the sharing of data and documents as well as the management of electronic assets in general and of Web content in particular. The data and knowledge source layer gives some examples of the wide variety of electronic sources for data and knowledge which have to be integrated into the KMS or at least accessed through the KMS. [55]

The features of the knowledge management system architecture suggested by Staniszkis [96] are grouped into six principal feature sets where each set contains specific tools (Figure 32, see Appendixes):

- collaboration,
- security,
- information integration,
- search,
- knowledge representation,
- repository.

Some of the features are already common in the advanced content management systems, referred to as the corporate portal platforms, some other are subject to the on-going KMS research efforts [96].

Abar et al. suggest a knowledge management system architecture based on an agent-based distributed information processing system (ADIPS) [1]. The architecture shown in Figure 33 has three levels (see Appendixes):

- interface layer,
- intelligence layer,
- structured resource layer.

At the interface layer users interact with the system. The personal assistant agent represents the interests of the user and provides the interface between the user and the system. Intelligence layer agents can check the dynamic conditions of the knowledge management environment, reason to interpret those perceptions, solve problems, determine actions, and finally act accordingly. The structured resource layer is the most considerable in size of the information space. The variety of resources residing in it makes network information access a daunting task. Therefore, knowledge should be organized by an appropriate taxonomy for the ease of its retrieval. [1]

Dzemydienė suggests a componential knowledge management system architecture which consists of a knowledge portal, knowledge components, and a knowledge repository [27]. The architecture is shown in Figure 34 (see Appendixes). The component architecture is a representation of the underlying set of interrelated components that define and describe the solution domain required by the business to attain its objectives and achieve its business vision. The architecture is an amalgam of engineering art and engineering science [32]. A knowledge portal is a web site where members of a knowledge community begin to enter, find, and access knowledge using the various knowledge artefacts to solve daily problems. The componential knowledge management system architecture takes an important part in knowledge management and integrates many methods of knowledge representation. The integration part uses an ontological model [27]. The authors suggest usage of such an architecture in distance learning systems proposing to integrate a domain ontology into a system of selected architecture [25].

Figure 35 (see Appendixes) depicts an overview of the service based KMS architecture suggested by Woitsch and Karagiannis. The dashed line indicates the border between the Internet and the inner organisational system. The web services implementing KM services are deployed by vendors and categorised using UDDI (universal description, discovery and integration) services. The KM dimensions are used to classify these KM services in the organisational service repository (UDDI). The KM-Service is a semantic web-service that is defined in the context of KM. This means that semantic services are defined by a KM–framework consisting of KM dimensions and algorithms to classify and select services. All user requests are coordinated by the KM portal that finds the most appropriate KM service, either in the organisational service repository or in external service repositories. This architecture enables a very dynamic KM approach by separating the technical implementation from the semantic requirements. [108].

Lupeikienė and Vasilecas suggest an enterprise knowledge system architecture from a knowledge worker's point of view [53]. They excerpt two types of work places – manager and subordinate. The subordinate's work place, where situations are specified and known in advance, has a fixed knowledge base. The knowledge in this knowledge base comes from business processes like professional instructions, regalement, etc. Implicit knowledge is not taken into account. The manager's work place, where decisions are made and situations are not defined, has a knowledge base which uses knowledge from subordinate's knowledge base and is constantly updated. Implicit knowledge is stored here as well. The knowledge management system is a part of an enterprise information system [54]. The authors emphasise the problem of storage of different types and structures of knowledge.

British Petroleum's knowledge management approach is encompassed by a simple framework, which describes a learning cycle – before, during and after any event – which is supported by simple process tools (Figure 36, see Appendixes) [18]. The framework assumes that business units and teams work on specific projects with associated goals. Processes to learn before, during, and after a project aim to capture and apply knowledge in order to increase performance. Once the project is defined and the project team has been assembled, a "Learn before" process should take place. The objective is to identify knowledge from people, documents, and Knowledge assets, which can improve the way the project will be delivered. During the "Learn before" stage, knowledge is acquired so that the project team can begin their work better prepared than they would otherwise have been. During the project, methods and tools are available to ensure that the team will "Learn during" the project [73]. When the project is complete, the goals of the project are compared to the results and a process kicks in for "Learning after" the project. This ensures that any knowledge that could be useful to future teams working on similar projects is identified and captured. At British Petroleum this knowledge capture takes place by creating retrospects and learning histories [73].

2.3. Classification of knowledge management systems

There are no classes or types of knowledge management systems agreed on in literature. Different authors made a different classification of KMS which I supplemented with some new in the last row of Table 6:

Table 6. Classification of knowledge management systems

Classification	**Description and author**
By the SECI model	Marwick does it by impact of Nonaka's socialization, externalization, combination, and internalization processes [76], [63].
By the KMS components	Borghoff and Pareschi classify the KMS using their knowledge management components: repositories and libraries, knowledge worker communities, knowledge cartography/mapping, and knowledge flows [13].
By the source of the knowledge being supported	Hahn and Subramani classify the KMS by the source of the knowledge being supported: structured artifact, structured individual, unstructured artifact, or unstructured individual [38].
By the knowledge spectrum	Binney classifies the KMS using the knowledge spectrum. The knowledge spectrum represents the ranges of purposes a KMS can have and include: transactional KM, analytical KM, asset management KM, process-based KM, developmental KM, and innovation and creation KM. Binney does not limit a KMS to a single portion of the knowledge spectrum and allows for multi-purpose KMS [12].
By integrative or interactive	Zack classifies KMS as either integrative or interactive. Integrative KMS support the transfer of explicit knowledge using some form of repository and support. Interactive KMS support the transfer of implicit knowledge by facilitating communication between the knowledge source and the knowledge user [113].

End of Table 6

Classification	Description and author
By the type of users being supported	Jennex and Olfman classify the KMS by the type of users being supported. Users are separated into two groups based on the amount of common context of understanding they have with each other resulting in classifications of: process/task based KMS or generic/infrastructure KMS. The process/task based approach identifies the information and knowledge needs of the process, where they are located, and who needs them. The infrastructure/generic system based approach concern of the technical details needed to provide good mnemonic functions associated with the identification, retrieval, and use of knowledge [43],[42].
By support of KM processes	KMS can be classified by support of KM processes: knowledge creation, knowledge transfer, knowledge applying, and knowledge storage/retrieval.

In the next sections KM solutions and systems are analysed by dividing them into two classes: industry and open source.

2.4. Current state of knowledge management systems

There are many commercial and open source systems which could be deployed for knowledge management solutions in the market.

SAP suggests classifying the entire spectrum of unstructured content, making it accessible to users and adapt the knowledge management approach in existing business processes, user behaviour, and system landscapes. The SAP® Enterprise Portal (SAP EP) component of the SAP NetWeaver is used for that solution [47].

One of the pioneers in the knowledge management area APQC'S to KM looks from best practises point of view. They focus on creating communities of practice and their relationships to the organizations' business strategies [5].

One interesting research from a knowledge management point of view was made by Maurizio Rigamonti at Fribourg University, Switzerland. The author puts his work into mining, indexing, and retrieval area, but it could be very useful as well for knowledge creation, especially where one needs to deal with implicit knowledge. He suggests a method for structuring and browsing multimedia collections of meetings by analyzing a single medium and eliciting its relationships with the other multimedia documents belonging to the same event. Furthermore, he extracts the correlations existing in an entire collection of meetings [83]. This method could be integrated as a part of a knowledge management system to manage collected implicit knowledge and combine it with existing implicit and explicit knowledge.

Dzemydienė analyzes the development of knowledge management systems and knowledge representation from the first classical methods until current state of the art. More can be found in her monograph [26].

Mentz et al. provide an overview of the Know-Net system [129], which helps to collect and categorize internal and external information by allowing knowledge workers to capture knowledge assets and link them to their context into a knowledge repository, to reuse knowledge assets using customizable knowledge navigators, to find knowledge assets using both textual and graphical searching mechanisms, and to collaborate and share knowledge assets via on-line workspaces [65].

OpenText Livelink suggests several products for KM solutions like Livelink ECM Collections Server, Livelink ECM Discovery server, Livelink ECM Federated Query Server, Livelink ECM Livelink ECM Knowledge management, Livelink ECM Library management, Open text eDocs KM, Open text eDocs Search server. Maier presents a more detailed analysis about usage and features of these products in [56], also hiswebsite [130].

Some products from IBM like Lotus Notes, Lotus Discovery System could be used to satisfy KM needs. Lotus Discovery Server is described more detailed. One of the knowledge management systems is IBM Lotus Discovery System (LDS). It provides search and expertise location solutions designed to ensure that the relevant knowledge and collective experience of an organization are readily available to help individuals and terms solve everyday problems [68]. LDS is able to automatically find, organize, and map disparate content, build a network to locate subject matter experts, add value to content by maintaining its context and by incorporating the opinions and judgments of individuals. It comprises a large, active content catalog and a set of services that collect, collate, and maintain information in the catalog. The catalog is an index to the written information and expertise that exist within an organization. The server regularly refreshes the catalog by tracking content, user interests, and usage activity. It delivers a great deal of information about an organization in terms of where things are, who knows what, what is important, and what subjects generate the most interest and activity [78]. Through a combination of automatic processes and administrative tools, the Lotus Discovery Server can perform the following tasks:

- create a unique Knowledge map, or K-map, of an organization's content, experts, and community workspaces,
- generate affinities representing expertise to business topical areas,
- mine skills to create complete expertise profiles,
- dynamically calculate and assign document and affinity values,
- group and organize documents to business category areas,
- search for documents, people, and topics across disparate sources [103].

It provides main components like K-map or taxonomy, spiders, metrics, profiles, etc. [78]. The IBM Lotus Discovery system is shown in Figure 28 (see Appendixes). K-map is a graphical representation of an organization's knowledge. It displays a hierarchical set of categories and documents people can use to find information. Additional information about relationships between people and document activity adds value and context to the user's search and retrieval experience. K-map displays related documents, people and places in categories, so users can browse and search for information in context 4. Spiders are optimized content access and extraction technologies that run on the Lotus Discovery server. Their function is to connect to the specified source content repositories and information sources, extract information/knowledge, and bring it to the Discovery server for analysis and organization to taxonomy [103]. There are different types of spiders for different content. Metrics is a Discovery server process that evaluates documents, people, and categories of information, and then determines the relationships between them. Metrics consist of two basic processes: metrics collection and metrics calculations. The metrics collection process gathers usage statistics for data within the spider's sources, and the metrics calculations process calculates relative data values based on these statistics. These statistics, and the calculated values, are known as metric values [103]. IBM Lotus Discovery system on the one hand is a very complex system and solves many tasks of knowledge management, but on the other hand is very difficult to deploy and implement. It could be useful and helpful for big organizations with many employees and knowledge sources but would not be cost-efficient and time-efficient for small organizations. IBM Lotus Discovery system could be classified as integrative and interactive, also as infrastructure/generic system and could have an impact on all processes of KM: knowledge creation, transfer, storage/retrieval and application. LDS is suitable for organizations with already deployed ICT infrastructure.

Despite the versatility of LDS, IBM stopped to support it and divided the system into different modules like OmniFind Discovery [105] with special orientation to search on web.

Another product which could be used to solve KM tasks is the Office SharePoint Server from Microsoft. Microsoft Office SharePoint Server 2007 provides a single, integrated location where employees can efficiently collaborate with team members, find organizational resources, search for experts and corporate information, manage content and workflow, and leverage business insight to make better-informed decisions [122].

Office SharePoint Server 2007 supports all intranet, extranet, and Web applications across an enterprise within one integrated platform, instead of relying on separate fragmented systems. Additionally, this collaboration and content management server provides IT professionals and developers with the platform and tools they need for server administration, application extensibility, and interoperability [66]. Here is a list of typical functionality that can be built using Microsoft Office SharePoint Server 2007:

- libraries such as documents, knowledge base, forms, wikis,
- communication like announcements, contacts, discussion board,
- tracking like links, calendar, tasks, project tasks, issue tracking, survey,
- custom lists like keywords, custom, custom list in datasheet, import spreadsheets,
- web sites like basic pages, web part pages, sites and workspaces.

A well planned and deployed solution with Microsoft Office SharePoint Server 2007 could promote better collaboration, content management, documents management, knowledge discovery, business intelligence and solve many knowledge management tasks. It is supposed to be an organization collaboration platform but could take part in Nonaka's SECI processes, it can also be seen as an infrastructure/generic system and has an impact on knowledge creation, transfer, storage/retrieval and apply processes.

There are many open source solutions which could be used in the KM area. One of them is an academic open source project, the concept browser Conzilla. This knowledge management tool has been developed within the Knowledge Management Research group at the Royal Institute of Technology in Stockholm [120]. Concept formation helps us to disregard what is inessential by creating idealized structures that focus on what is essential. Efficient concepts disregard as much as possible in such a way that it is noticed as little as possible [70]. Conzilla is written in Java and uses RDF as the underlying format for exchanging information. The program has a clear object-oriented structure that separates the underlying logic from the presentational graphics. It can easily be adapted to different presentational styles and cognitive profiles [77], [71]. Conzilla presents knowledge in terms of specific maps, Context-maps. A Context-map displays nodes and arcs, from now on referred to as concepts and concept-relations, with specific box-forms, icons, arrow-heads, line styles, etc. [124]. There is an example of a conceptual map made in Conzilla in Figure 26 (see Appendixes).

The Conzilla "mantra" is /content/ in /contexts/ through /concept/, which means that a concept should be regarded as a delimiter between its /inside/, which stores its content and its /outsides/, which represent the contexts (maps) in which the concept appears. By right-clicking on a concept, one can navigate between all the different contexts where it appears. This type of /contextual-neighborhood navigation/ provides a very powerful way to cross reference information [29].

Conzilla has features like [124]:

- Conzilla supports an open ended set of different diagram types. Per default the UML class, activity, use case, and process diagrams are provided,
- each concept and concept-relation has a "life of its own". This means that the same concept and concept-relation can occur in different maps, which is in accordance with the knowledge manifold [72] information topology. It is also possible to provide a simple hyperlink from each concept or concept-relation to another context-map,
- context-maps, concepts, and concept-relations can be endowed with metadata,
- concepts or concept-relation can be filled with content components in the form of links to other resources, e.g. web pages or books in a library, persons, etc.,
- a context-map, a concept or a concept-relation can be distributed, allowing people to extend them easily. In this case they must be loaded from different sources. Each of these sources we refer to as a Knowledge Patch,
- a Knowledge Patch typically contains a set of Context-maps and has a responsible publisher which we call a knowledge gardener,
- the appearance in Conzilla is controlled by stylesheets,
- everything is stored in RDF allowing integration with other tools,
- Conzilla includes an editor for Context-maps,
- since Conzilla 2.1 context-maps can be published easily to an information directory: Collaborilla [28],
- published maps can be loaded by everyone who has access to Collaborilla (which means literally everyone, since this access is not restricted),
- everyone can comment on or contribute to published maps.

There is an example of a map with comments of another researcher in a red rectangle shown in Figure 27 (see Appendixes). The conceptual modelling tool would seem to be a promising approach even for analyses of describing the different conceptions of the world around us [110].
Conzilla is an elaborated tool for knowledge sharing among researchers, learners, etc. It allows creating conceptual maps, share them, and receive feedbacks or comments from other participants. Despite the nice conception it has a quite difficult usability. Conzilla could be classified as supporting analytical KM, structured individual knowledge and in the knowledge management architecture it takes place in the knowledge cartography/mapping architecture. Furthermore it supports combination and externalization processes in SECI spiral.

Another open source example is the Real time communication tool – FlashMeeting. FlashMeeting is an application which allows with usage of a standard web browser to meet and communicate with people around the world in real time [118]. FlashMeeting was created as discussion supporting tool for learners which main purpose reflect on the collected experiences, which should be articulated [110]. To use a meeting one needs to pre-book it (as a registered user) and after one receives a password for the meeting from the FlashMeeting server. The person who booked the meeting invites people who wish to participate by sending the link to the meeting. The system favours simplex audio, allowing only one person to broadcast at any one time, suitable for meetings with multiple participants. In order to broadcast, one has to push-to-talk, while attendees wishing to speak, raise a symbolic hand and queue until the current speaker stops broadcasting, or click on the interrupt button. Other communication channels include text chat, voting, displaying mood indicators, URL firing and a whiteboard facility for uploaded slides and real-time annotations. One of the principal features of FlashMeeting is the ability to record meetings. These recordings form effectively a complete record of the event including the browsing of individual broadcasts by time code and participant name, text chat, voting, fired URLs, whiteboards, etc. [101]. A meeting on FlashMeeting is shown in Figure 25 (see Appendixes). Flashmeeting could be used for lectures, interviews, meetings, etc. FlashMeeting is an application based on the Adobe Flash plug in and Flash Media Server [118]. The system architecture is shown in Figure 25 (see Appendixes). It has been developed by the Centre for Research in Computing as part of Knowledge Media Institute at The Open University in UK [114]. FlashMeeting is a sophisticated KM tool especially in the socialization and externalization processes from Nonaka's SECI spiral. By the source of the knowledge being supported it could be classified as support of unstructured personal knowledge.

2.5. Conclusions of the 2nd chapter

Many of the architectures of knowledge management systems described above are layered. Some of them are service-oriented or componential. None of these architectures excerpts a knowledge management processes layer. Furthermore, the only architecture that pays attention to knowledge management processes at all is the KM services-oriented architecture. However, service-orientation has besides its advantages (e.g. flexibility) also its drawbacks (e.g. considerable complexity). Other authors do not discuss the ability of including KMP into their system.

Other architectures like the British Petroleum look at processes but from a learning processes point of view and are project-centred.

Some architectures do not pay enough attention to implicit knowledge and some of them even do not have a collaboration or communication level (Metadata oriented, Agent-based distributed information processing system, Componential knowledge management system architectures).

To sum up the analysis of architectures, we can retain that most of them are technology oriented, do not consider knowledge management processes, or are quite difficult and heavy.

3

A system architecture centred on knowledge management processes

In this chapter an architecture for knowledge management systems which is oriented to knowledge management processes (KMP) is suggested (3.1. Architecture of knowledge management system). After – with usage of unified modelling language (UML) diagrams – information and communication technologies (ICT) which could be used for each KMP are proposed.

3.1. Architecture of knowledge management system

Current status of knowledge management is a tight coupling on the technical layer but a rather loose and weak integration at the management layer. The challenge of today's research is to integrate knowledge management not only at the technical but also on the management layer [109].

KMS designers must take a holistic approach to designing inter and intra organizational "systems" with due consideration not only for the technological design, but also for the design of strategic sustainability of these systems. This approach is expected to provide the needed balance of integration and flexibility required for next generation KMS architectures [60].

Knowledge management processes orientation reduces the aforementioned discrepancy. First, it shifts the focus from technology to management. This technology independence heightens the flexibility when implementing the concept. Second, aligning KM to the current trend of business process orientation in other management disciplines further facilitates their integration.

An architecture of KMS from the point of view of knowledge management processes is proposed. Every process is supported by different kinds of technologies and all these technologies are integrated into the system. Note that a technology could be used for different KM processes and the same process could use several technologies. The architecture is divided into three main layers and is centred to KMP:

- resource layer,
- knowledge management process layer,
- user interface layer.

The suggested KMS architecture is shown in Figure 1:

Usage of ICT depends on what and how knowledge management processes are supported. It considers in addition already existing ICT in the organization. Systems interoperability and handling standards are crucial in the development of a knowledge management system in an organization.

User interface level

At the user interface layer a knowledge worker connects and participates in the knowledge management processes by putting and receiving knowledge using a web browser or another access service. Studies made by many researchers showed that the most compatible way to access KMS is a single point access like browsers.

The user interface depends on the user role in the knowledge management system. It can be organization employees, external users and customers, partners.

Knowledge management processes level

We suggest to use the four knowledge management processes described by Alavi and Leidner [3] in the KMS architecture:

- creation,
- storage/retrieval,
- transfer,
- applying.

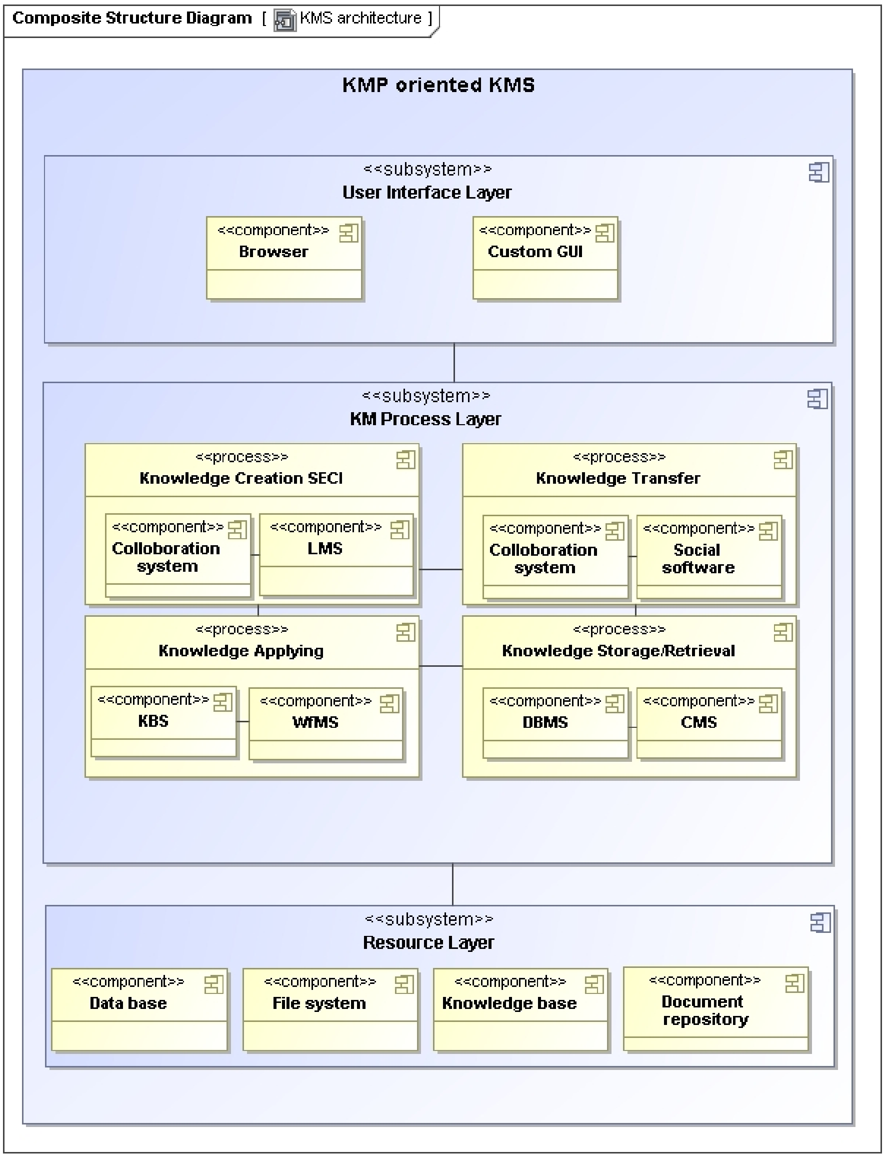

Figure 1. Knowledge management processes oriented architecture of knowledge management systems

Some other authors divide knowledge management processes into more steps, but most of them either repeat or could be generalized to the four processes detailed by Alavi and Leidner. Furthermore, these authors are among the most cited in academic literature.

The knowledge creation process was detailed by Nonaka as the SECI spiral [76]. For each of these processes usage of different ICT is proposed and detailed with UML.

Information and communication technologies for knowledge creation

Knowledge creation is described as the conversion between explicit and implicit knowledge and is divided into four stages: socialization, externalization, combination, internalization [76].

ICT could participate in these processes by collecting implicit and explicit knowledge during knowledge creating, then to structure and convert it into a searchable form and use it in other KM processes. Figure 2 shows the knowledge creation process in a UML Activity diagram.

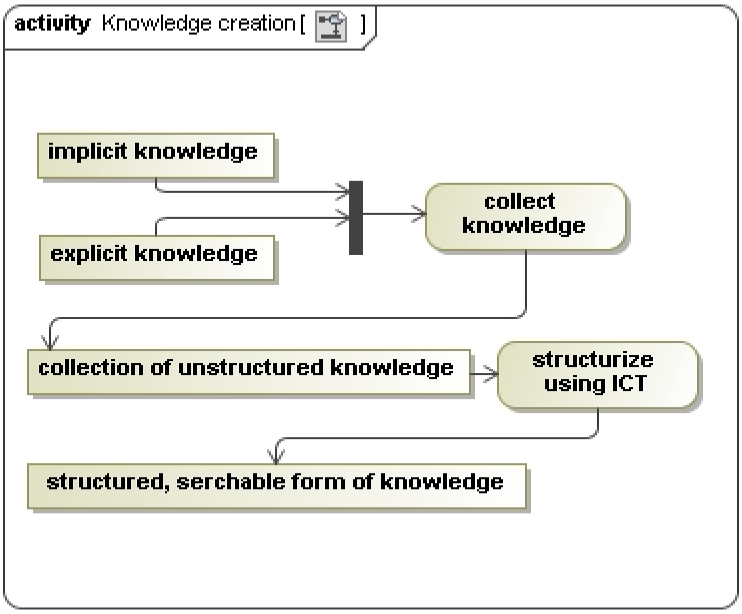

Figure 2. Knowledge creation with help of information and communication technologies

Each stage of the knowledge creation process is detailed below.

Socialization

Socialization happens when people interact with each other and share their knowledge. Taking part in this process is one of the hardest tasks for information and communication technologies, but still some could be applied such as chat, videoconferencing, etc.

Figure 3 shows the conversion of implicit knowledge within a chat. Each chat participant chats and writes his implicit knowledge in text which could be summarized and structured after by text mining or other technologies. A mechanism should be provided to let the participants choose themselves which chat should be handled by technologies not to make people avoid communication.

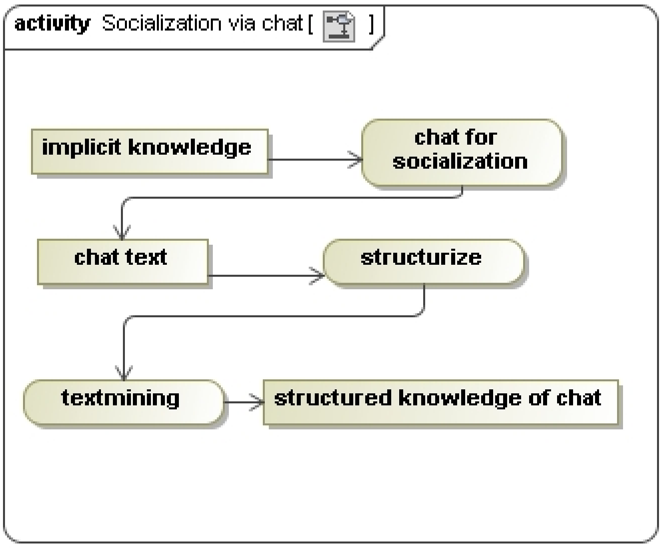

Figure 3. Socialization using chat

The UML Activity diagram in Figure 4 shows an example of socialization supported by videoconference. People discuss and share their implicit knowledge in a video conference. Voice records collected in this process could be arranged by speech recognition and after processed by text mining and other tools.

With the examples of technologies which could be used for socialization mentioned above only a small part of implicit knowledge can be collected by ICT.

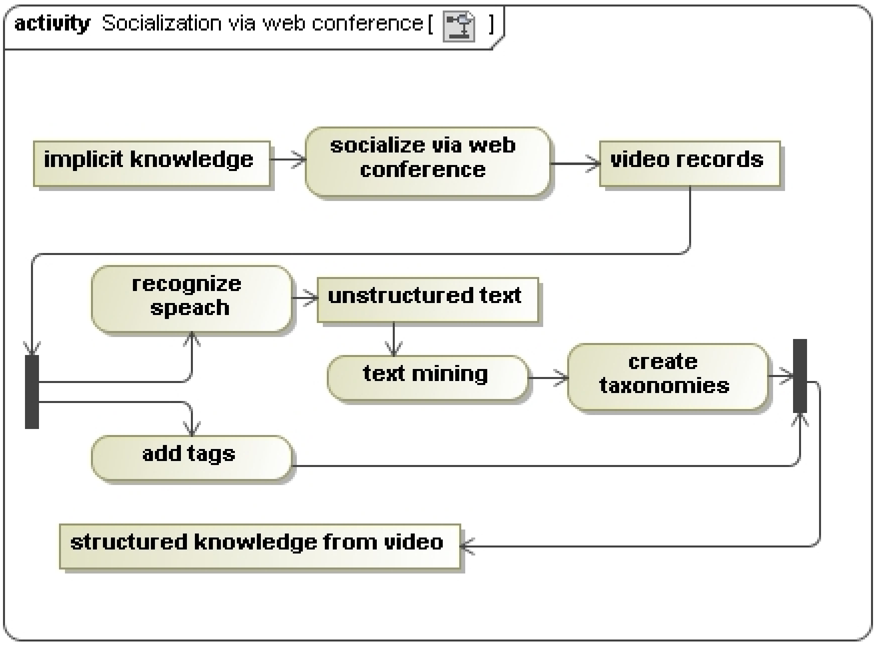

Figure 4. Socialization via web conference

Externalization

Converting implicit knowledge to explicit is externalization. Information and communication technologies could support this process by forums, questions-answers bases, Web 2.0 social software, etc.

Figure 5 shows the workflow of implicit knowledge conversion to explicit with contribution of a knowledge base.

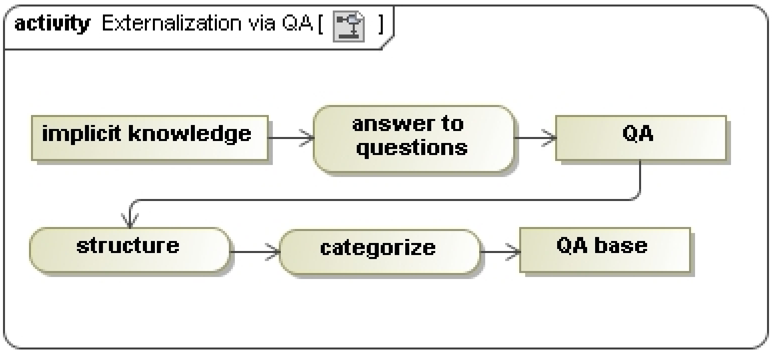

Figure 5. Externalization creating questions-answers base

In Figure 6 the externalization of implicit knowledge via a forum is showed. Text written in a forum is structured by text mining tools, keywords are added.

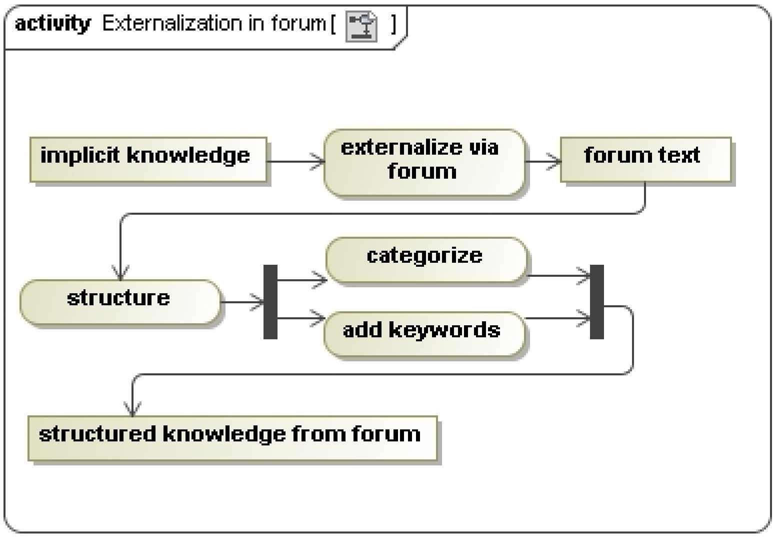

Figure 6. Externalization in forum

Figure 7 shows an example how the social software blogging takes part in externalization processes.

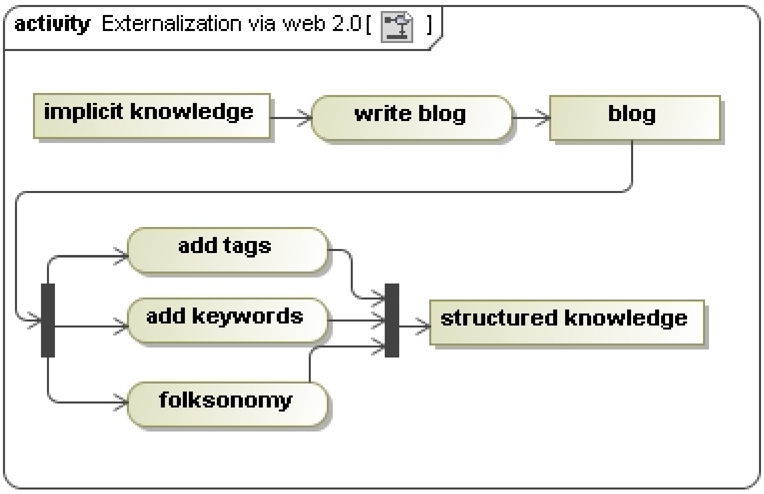

Figure 7. Externalization in Web 2.0

Combination

Combination could be influenced by ICT the most because it is an interaction between explicit knowledge. Here many information management technologies play a big role. For example an explicit knowledge artefact document could be processed by many technologies as shown in Figure 8, to get more structured knowledge which could be easier searched and used for other purposes like detecting the experience of a person in a particular area (refer Figure 8).

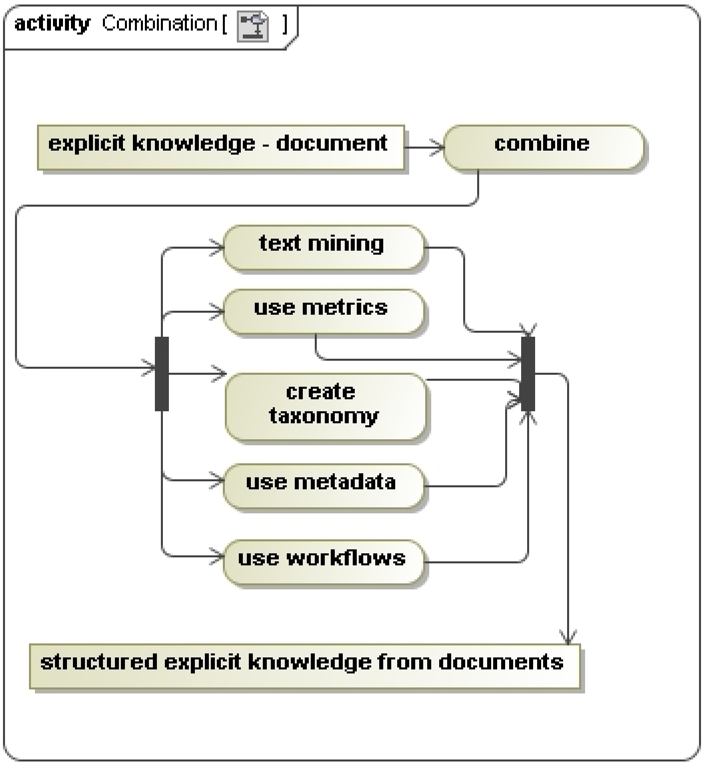

Figure 8. Combination of explicit knowledge

Internalization

Internalization happens when people learn from documents, books, etc. and explicit knowledge becomes implicit. This process could be supported for example by learning technologies (Figure 9).

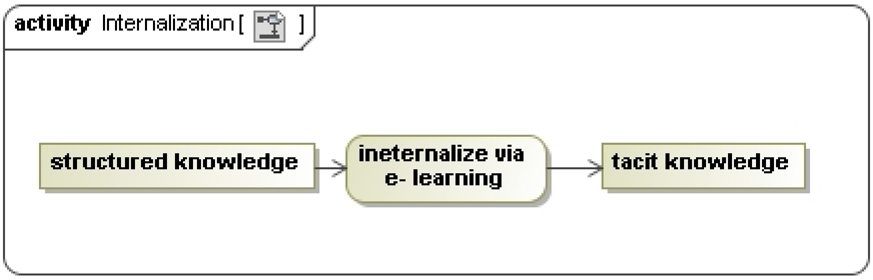

Figure 9. Internalization via learning activities

Information and communication technologies for knowledge storage/retrieval

Storage of semi structured data like messaging or learning objects, multimedia or experience and knowledge directories require additional ICT like content or document management systems, knowledge bases together with traditional relational data base management systems. The organizational knowledge is stored in various forms like documents, multimedia bases, knowledge artefacts which come from knowledge creating process, etc.

Information and communication technologies for knowledge applying

Knowledge applying happens when existing knowledge are added, used and reused by other knowledge. ICT can have a positive influence on knowledge application (Figure 10. Knowledge application process). Examples are workflows, knowledge bases, etc.

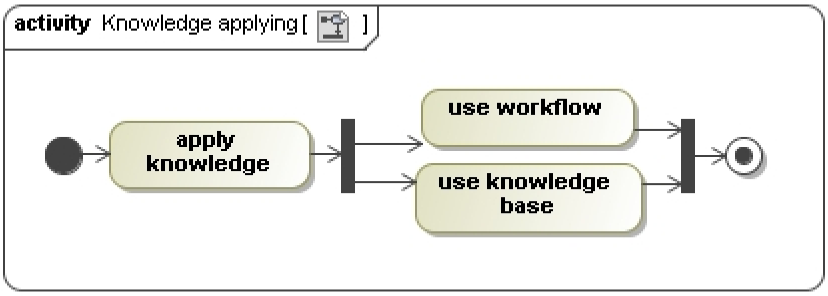

Figure 10. Knowledge application process

Information and communication technologies for knowledge transferring

Knowledge transferring occurs in different levels: between individuals, from individuals to explicit knowledge, from individuals to groups, between groups, across groups, and from groups to organizations.

Information and communication technologies can support knowledge transfer by creating collaboration environments, video conferences, etc. (Figure 11) [131].

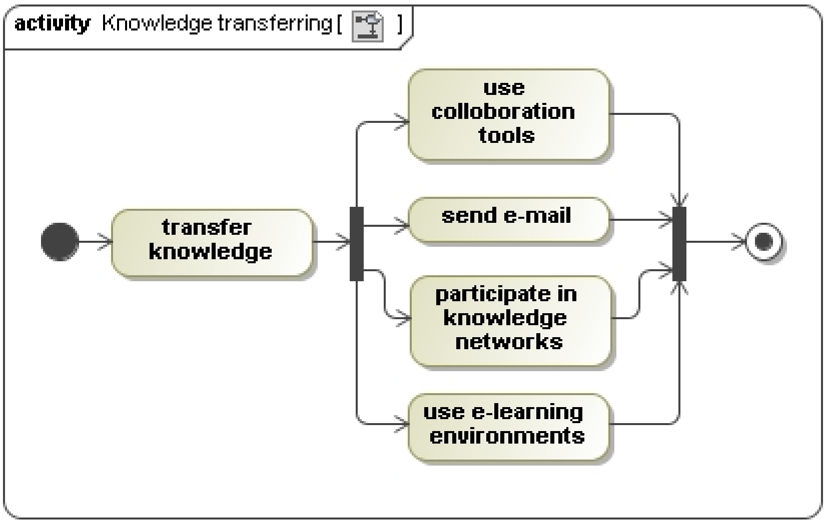

Figure 11. Knowledge transferring process

Resource level

The resource level contains knowledge base, files systems, documents repository, data base, etc. This level depends on organization resources repositories.

3.2. Conclusions of the 3rd chapter

The suggested knowledge management system architecture is oriented to knowledge management processes, which were suggested by authors from the knowledge management area. These are knowledge creation, storage/retrieval, applying, and transferring. Centring to KM processes improves the integration with other disciplines on the management level. Furthermore, it ensures that implicit knowledge will be taken into account as well. Application of different information and communication technologies for each of the processes makes the system more flexible. In particular it enables a step-by-step implementation or adoption of KM in enterprises as one can concentrate on one particular process at a time (e.g. the currently most important). Another important implication of the flexibility is the ability of integrating existing information and communication technologies in organizations with a combination of new ICT taking explicitly KM processes into account. This clearly increases significance and efficiency of a knowledge management system in practice.

4

Knowledge management implementations in organizations

In this chapter the suggested knowledge management system architecture and the modelled KM processes are applied in different environments: education, public and business area.

I start from – Europe Union structural assistance portal (4.1. Knowledge portal), continue with capturing implicit knowledge and converting into explicit via videoconferencing and storing it in a collaboration environment (4.2. Knowledge capture from knowledge creation) and finish about KM applications in technology enhanced learning (4.3. Knowledge management system in technology enhanced learning).

4.1. Knowledge portal

Increasingly knowledgeable citizens require governments to be on top of newly created knowledge, as it is increasingly rapidly produced by more differentiated actors [20].

The suggested KMS architecture and modelled ICT for different knowledge management processes is used for the Europe Union (EU) structural assistance knowledge portal considering the specific requirements and constraints.

Europe Union structural assistance knowledge portal: the problems and purposes

The problem and necessity to apply knowledge management solutions originated from the participation of 15 public institutions involved in an EU structural assistance management in Lithuania. Therein, informing ways like advertising in newspapers, putting information to their own web sites, organizing seminars and meetings or other resources have been used. For a person who was interested or involved in the EU structural assistance it was quite hard to find integral, qualified and trusted information. For that reason the decision has been made to create one single knowledge portal with information, knowledge and experience about the EU structural assistance (www.esparama.lt). For that the portal's visitors have been divided into target groups to present information and share knowledge in a more appropriated way for every target group and correlated with their needs and interests.

The employees of all involved institutions work with the publishing of EU structural assistance but they are not IT specialists. Therefore, they needed an easy way to put information into the portal to support, update and make the portal alive.

Solution

To make knowledge better accessible and applicable, to support its creation, transfer and storage the KMS architecture suggested in the fourth chapter has been used.

The user interface level in the portal was divided into so-called knowledge zones which are oriented to target user groups. These target groups are:

- potential applicants for EU structural assistance,
- applicants and project promoters,
- general public,
- EU structural assistance managing institutions,
- English speaking EU citizens.

The knowledge management processes level consists of four processes which are supported by ICT.

The knowledge creation process or implicit and explicit knowledge conversion required for the institutions to put content in the portal like news, answer into the questions of visitors, create the frequently asked questions data base, create and share experiences about success stories, etc. A UML Activity diagram (Figure 12) shows the knowledge creation process. An employee of one of the institutions decides to create and publish a success story to the portal. For that he or she uses a content management system. The KMS collects many different kinds of information about current and expired EU structural assistance projects from the information system via web services. The employee additionally adds his experience, comments, photos, etc. and sends to publish into the Portal.

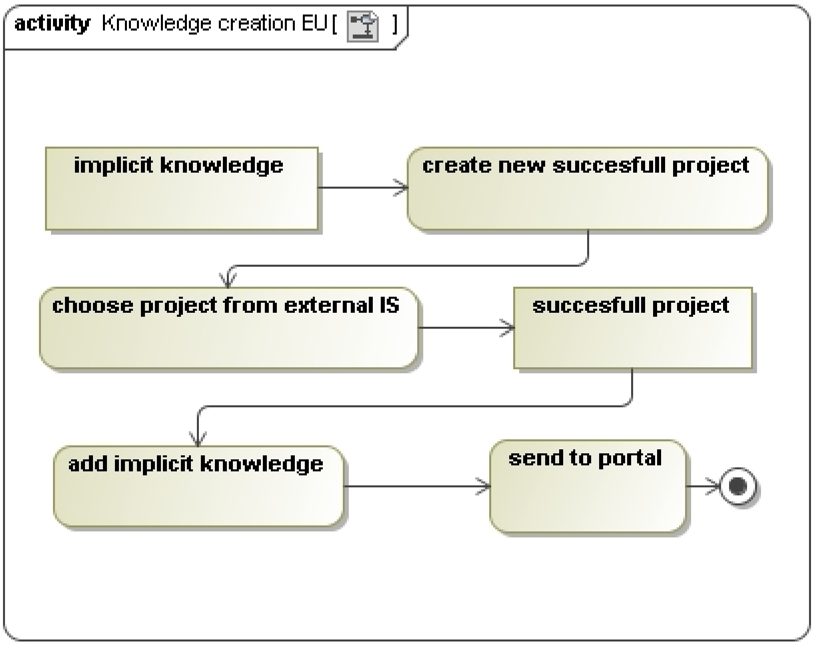

Figure 12. Knowledge creation and publishing in the Portal

To support different target groups, taxonomies have been created in a content management system and the main categories in the portal have been defined. Different types of taxonomies were created: institutions', portal logic's, knowledge types'. Those help that the same information would be related with different contexts and appear in different places in the portal depending on the semantics and needs. They also facilitated publishing of information in the portal for content managers because of the easier way to find a category. For example a user does not need to know the structure of the portal very well, but he or she could publish via the institution's taxonomy and the content will appear semantically in all categories of the portal set up in advance or chosen manually. Combination via taxonomies is shown in a UML Activity diagram (Figure 13).

Furthermore, metrics for combination process are used in order to select and present the most active and looked institutions in the front page.

For the externalization and socialization processes Web 2.0 technologies (forums, chats, experts comments) are used to share an experience of a person who is already involved with the EU structural assistance processes or just wants to post his or her opinion (Figure 14).

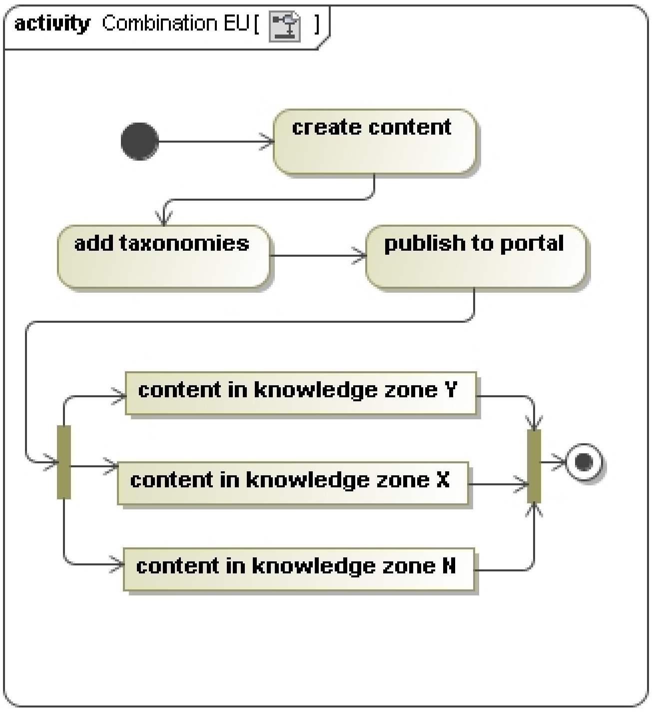

Figure 13. Combination via taxonomies

Knowledge transfer happens in several layers: between institutions in content management system, between institutions and visitors in the portal and among visitors in the portal with usage of Web 2.0 technologies. Users of the content management system fill up content creating templates and send to publish them into the portal. Transfer happens as well via e-mail by sending the answered question asked by visitor.

Knowledge applying goes via workflows. Depending on the content it follows the process shown in Figure 15. An employee of the implementing agency creates content and sends it to Intermedia body to add or review it. After that, Intermedia body sends it to Managing institution which also adds or reviews content and publishes it to the Portal. Like that, quality and internality of knowledge are ensured.

Knowledge is stored in a content repository, relational data bases and e-mail servers. EMC Documentum [116] and Liferay technologies [121] are used to implement the solution.

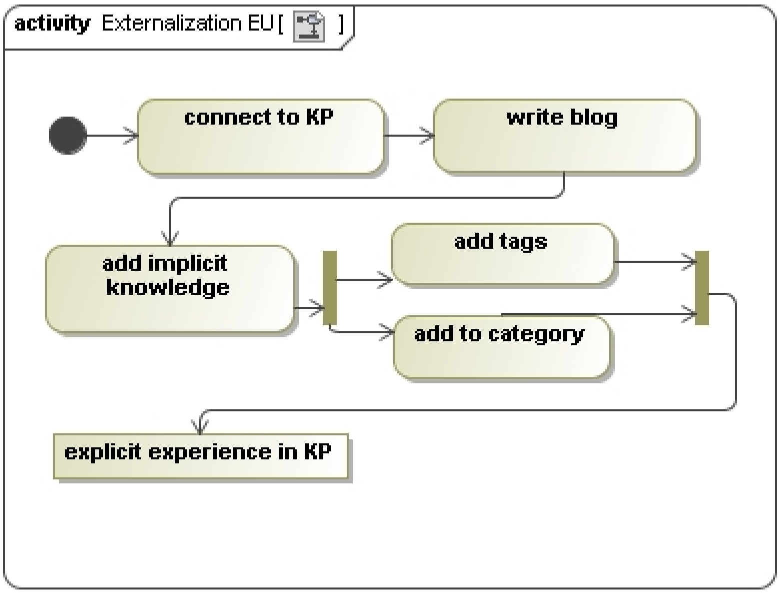

Figure 14. Externalization via Web 2.0 technologies

In Figure 38 the main page of the EU structural assistance portal is shown (see Appendixes).

Taxonomies and portal personalization are added for the 2007-2013 EU structural assistance period.

For the target group "Persons who already get the support" a registered participants' zone will be created, where after login they could see all information about their project's state and evaluation.

In the future with growing data, information and knowledge about EU support ontologies should be used for the representation of knowledge for the target groups to avoid manual work

The implementation of the knowledge portal about EU support significantly improved transparency and accessibility of information, knowledge, and experience about EU support. After analysis - which was made by independent experts - it came out that the portal is in the top rate in knowledge transferring to society.

Integration with other information systems has been made to present in one place all necessary information.

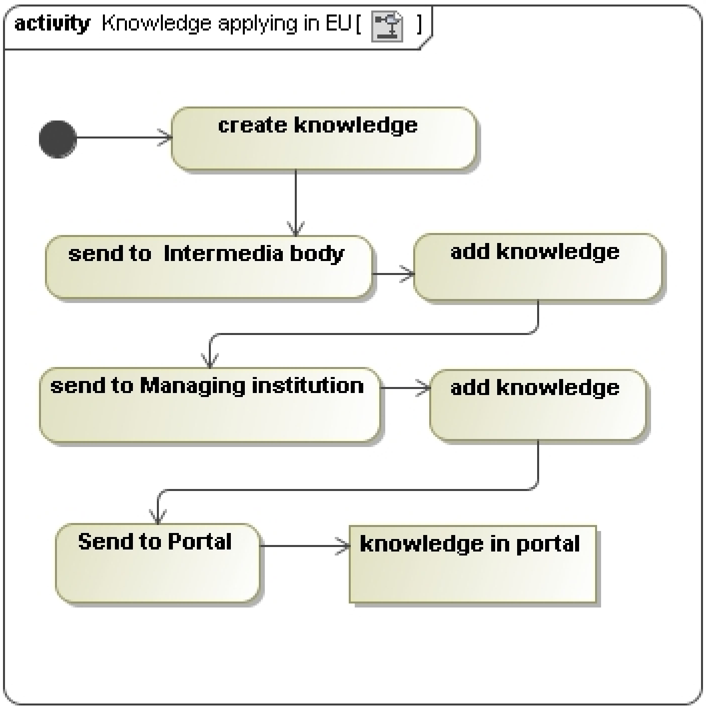

Figure 15. Workflow for applying and qualification of knowledge

Furthermore, it minimized costs and increased efficiency since 15 institutions can use one system for knowledge sharing.

4.2. Knowledge capture from knowledge creation process

Leading researchers in the fields of business strategy, organizational theory, institutional economics and economic development routinely emphasize the growth of the knowledge economy and by implication, there is a vital need for organizations to manage, share and leverage knowledge assets [44]. One of the most valuable assets in knowledge companies are employees, their knowledge and experiences.

Communication between employees in the organization, between employees and customers or external experts creates new knowledge, but this knowledge is not stored in the organization’s knowledge repositories. Converting implicit knowledge into explicit, collecting it and storing it is one of the hardest tasks for knowledge management.

Knowledge management practices that apply methods of management, known as project-based, are more widespread in organizations. Collecting and managing records of videoconferences and chat histories between employees in the organization, between employees and customers or external experts and especially in a collaborative, project oriented environment reduce consequences in cases where an employee leaves the company, other team members need to get familiar with the opinion of an expert expressed to only one person in the team, in misunderstandings between clients, etc.

For that purpose the suggested architecture of KMS is used in an already deployed project management environment at the joint stock company ERP, especially paying attention to the management of implicit knowledge.

The interface layer is supported by internet browsers with which users connect to the collaborative environment.

The knowledge creation process was improved with a messenger with video conferencing functionality which has been integrated in a running collaborative environment of the Joint Stock Company ERP [128]. As a collaboration environment EMC eRoom [117] technologies was used and into that environment the messenger Skype [127] was integrated, shown in Figure 39. Skype was chosen because of its wide dissemination – many employees and customers have already used it.

After login into eRoom, the user decides if he or she wants to connect to Skype from the collaboration environment. If the user agrees all records from videoconferences and chats will be stored there. Furthermore, the user has additional possibilities to see all participants of eRoom who use Skype, even if they are not in his or her Skype contact list. All stored items automatically obtain metadata like record data, time, participants, etc. The collaborative environment with the integrated messenger is shown in Figure 16 (see Appendixes).

The user can manually add tags for easier finding of items. All items are subject to common search of eRoom. Records belong to a particular room and only registered users can access that room and see the records. Besides the owner of the record, one can set permission rights manually to every user or user group. Collected implicit knowledge in the collaboration environment is shown in Figure 40 (see Appendixes).

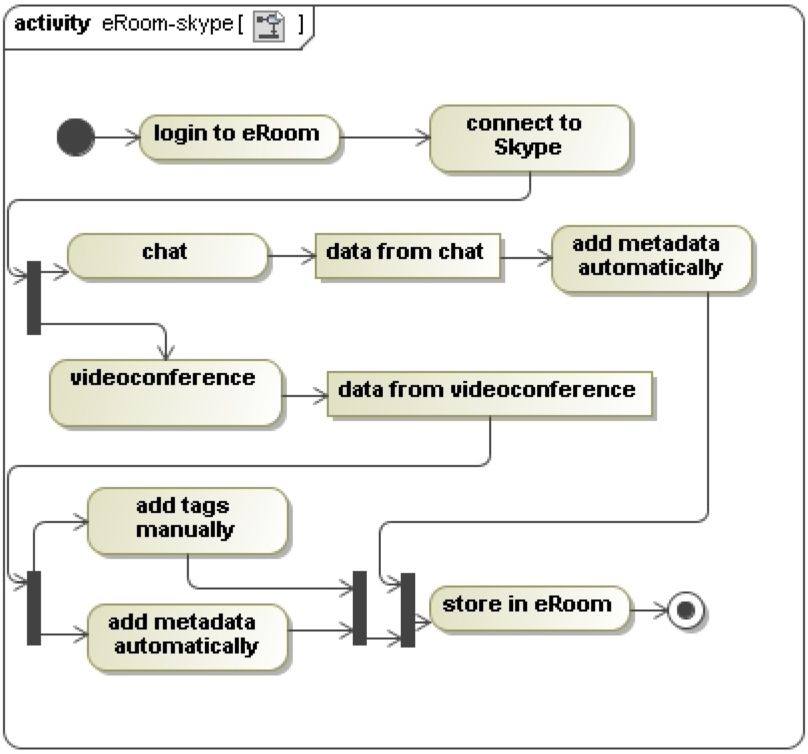

Figure 16. Socialization via instant messaging and video calls

Adding a video conference feature and after managing these records solves the socialization problem of knowledge management in collaborative environments. Users could look and share recorded knowledge and experiences from customers, experts and among themselves. Depending on the amount of records and their importance to the organization text mining, speech recognitions and other technologies could be added to analyze and combine knowledge.

The implemented solution demonstrates the flexibility of the suggested KMS architecture.

4.3. Knowledge management system in technology enhanced learning

Universities and other higher education institutions are recognized to be in the knowledge business [62], [34] as they are involved with knowledge creation, transfer and learning. University's competitive ability depends on the institution's capability to share, spread and adapt knowledge as well as it is created. Modern students will require regular updating of their knowledge, skills and competences. In this context, universities will be required to expand flexibility and innovative learning and teaching [51]. They must recognize and respond to their changing role in a knowledge-based society and need to be consciously and explicitly managing the processes associated with the creation of their knowledge assets [136].

Knowledge management could take an important part in educational processes at universities and especially in technology enhanced learning (TEL) between students and lecturers, among lectures, researchers, etc. where direct contacts are very often missing [138].

A student connected to an e. learning system needs to see not only all materials which could be necessary or interesting to him but also related works of previous students, lectures or students who are working on a particular topic, etc. Also the lecturer or researcher needs to see his colleagues' interest areas, publications, related documents, etc. or to say in knowledge management words the right knowledge for the right persons at right the time should be delivered.

To solve these problems a system architecture centred on knowledge management processes was chosen and integrated together with existing learning systems.

Infrastructure of technology enhanced learning

A learning management system's (LMS) primary function is to manage learner information, administration and access to courses. It also allows creating, managing and delivering trainings. It is most often referred to as the learning portal that links users with the various learning activities and can be used to manage the course catalogue and to link different types of e-learning activities together in order to deliver a blended solution [48]. Examples of LMS systems are Saba, Docent LMS, Blackboard, IBM Lotus LMS, MicroLink and TopClass, etc.

IBM learning technologies are used at the department Information Technologies in Vilnius Gediminas Technical University (Available at www.teta.vtu.lt/lms-lmm) [137], [48] since it became member of the IBM Academic initiative [126], [125]. The scheme of the TEL infrastructure at the IT department is shown in Figure 17.

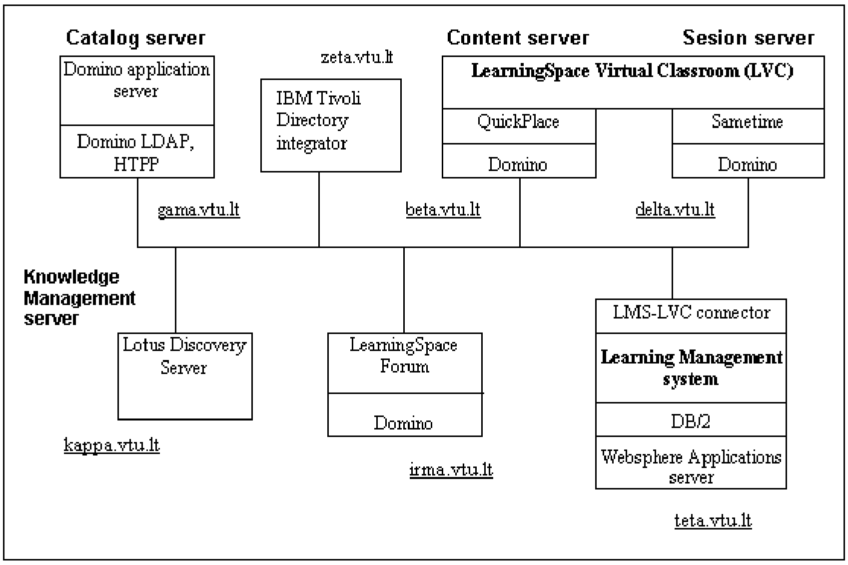

Figure 17. Infrastructure scheme of technology enhanced learning [136]

The learning management system relies upon a standard HTTP server for delivery and uses a relational database system for its data storage. The Delivery server is a LMS component that connects students to courses, performing tasks that support the sequencing, launching, and tracking of course content. The LMS requires that user information is stored in a lightweight directory access protocol (LDAP) directory. The directory contains general user information that may be accessed by more than one application. LDAP is the de facto standard regarding directory services and a guarantor for interoperability of heterogeneous platforms, systems and environments. Many learners have different roles and move within different parts of a large organization, and may often be a part of multiple user groups at the same time. In LMS, permissions can be granted to users by assigning them roles or by adding them to access control lists for specific objects. A user may have more than one role. [133]

The IBM Lotus learning management system provides a framework for delivering many types of trainings. It delivers learning management solutions to corporations, governments and educational institutions integrating its extensive learning capabilities in consulting, content design and development, infrastructure technologies, outsourcing and research. The IBM Lotus learning management system can be used for managing both classroom-based and e. learning activities, resources, curriculums and learning solutions. It organizes and delivers courses, tracks and reports on student activities and reserves instructors and resources enabling customers to manage their training program from a single platform [7].

LearningSpace – Virtual Classroom (LVC) provides a framework for designing, scheduling, managing, and delivering virtual classroom courses. Course developers can use the authoring tool (AT) or LearningSpace, or other tools on their workstations to create courses and export them to the learning management system as it supports the Shareable content object reference model (SCORM) 1.2 standard. SCORM [123] published by the advanced distributed learning (ADL) project, is a de facto standard for e.learning content. When course developers create course content in the AT, they can add materials for live sessions as one of the activities. This means that one can set up blended courses, which include live sessions. Live sessions are hosted on a LearningSpace – Virtual Classroom server, and courses chats are hosted on a Sametime server, online discussions are hosted on a Domino server. Also, a Domino server contains various libraries of data, such as various documents of the department:

- library of Bachelors' final works,
- Master theses,
- administration documents,
- library of e-books,
- news page,
- schedules,
- virtual jobcentre, etc. [48].

Content servers store course content files for use with the learning management system. The files are accessed from course outlines using URLs. For applications the WebSphere application server on the basis of Java, XML, HTTP and other technologies is used. Thereby, two different application servers that perform different functions are used in the distance education information system.

Knowledge management system

For such different amount of knowledge resources a knowledge management system was needed. The suggested knowledge management system architecture was applied and integrated together with LMS and other systems shown in Figure 17.

The user interface layer is supported by internet browsers which connect to the learning management system and mainly has three different types of users: students, learners and administration. The knowledge management processes are maintained with the IBM Lotus discovery system and LMS. Specifying the Lotus discovery server in the LMS settings enables a

Knowledge search link on the LMS home page that takes a user to the learning K-map (Figure 41, see Appendixes).

Knowledge creation processes are executed when new learning content is applied, when users participate in forums and discussions. Moreover, significant implicit knowledge management is made when lectures are recorded and stored in the system (Figure 18).

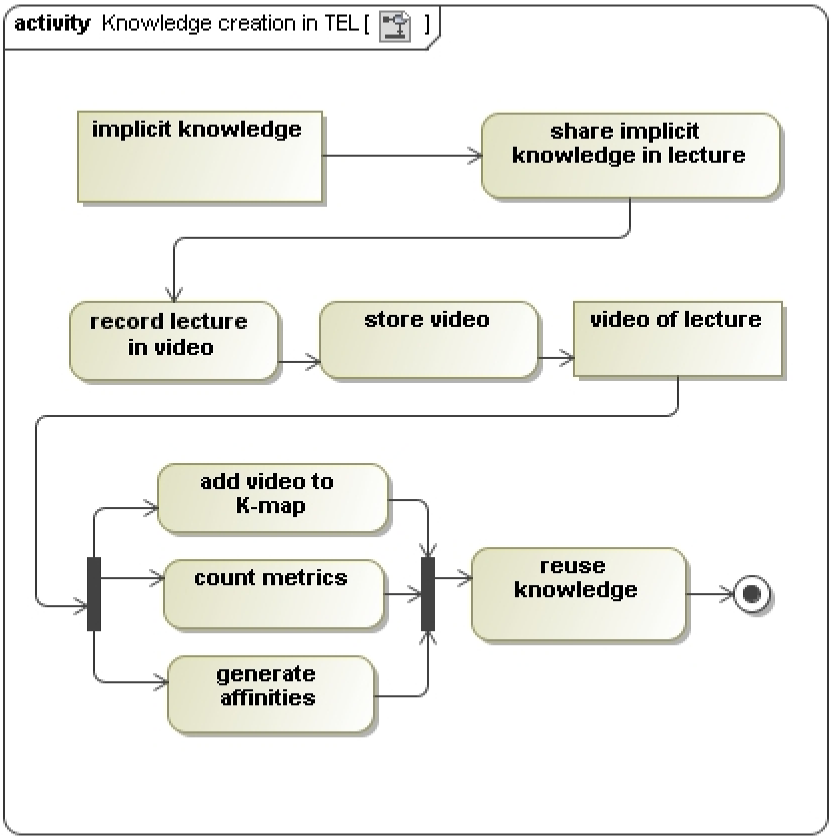

Figure 18. Knowledge creation process in technology enhanced learning

Implicit knowledge from chats and discussion forums are collected from Sametime and Domino servers as explicit knowledge from content servers and others as well [134], [138].

Students can find papers and works of previous students thus reusing and increasing the value of knowledge (Figure 19). Also, it could be used as a prevention of unfair behaviour of students. Consequently they can use and reuse previous papers and works of students [137].

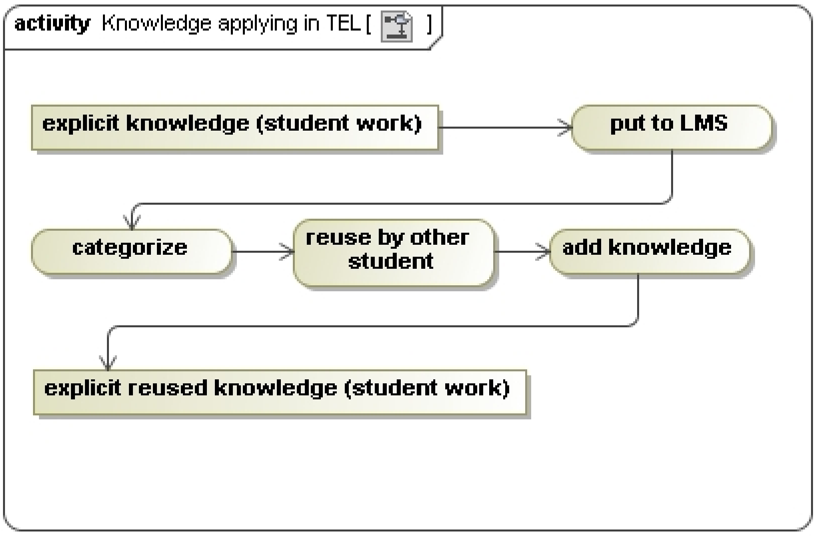

Figure 19. Knowledge applying by reusing knowledge

The eBooks library is stored in the content server. Using taxonomies functionality eBooks are represented in different categories (Figure 20. Combination via taxonomies).

The IBM Lotus Discovery server was used to maintain different sources and technologies which support knowledge management processes.

The implemented knowledge management system architecture helps learners to find and get necessary information from different information resources. Integration of LDS and LMS provides search results from across the data repositories on information relevant to the subject matter of the course. It is especially helpful and advantageous for TEL when a direct contact between the student and the instructor is absent [134].

Since IBM divided LDS into smaller pieces oriented to search and the decision to upgrade the LMS to a higher version has been made, these systems became incompatible.

For tracking and analyzing the behaviour of participants of learning processes the knowledge management system was not enough. To respond to user needs and realising the usability of LMS data mining technologies were added. For instance, modification of web pages to better fit for the user, web page creation that are unique per user or using the desires of a user to determine what documents to retrieve. These pieces of knowledge could lead to better course location on the web site and education strategies. Likewise, an analyst could perform OLAP on the data warehouse to determine what kind of courses are the most popular and what students attend the most. For instance, the dimensions could be student, event, date or teacher. As a measure we can choose a degree of learning, satisfaction, complementary or other. But there is one requirement for analyzed data: the data should be organized and stored so that it can be analyzed from any dimension or at any level of the hierarchy [135].

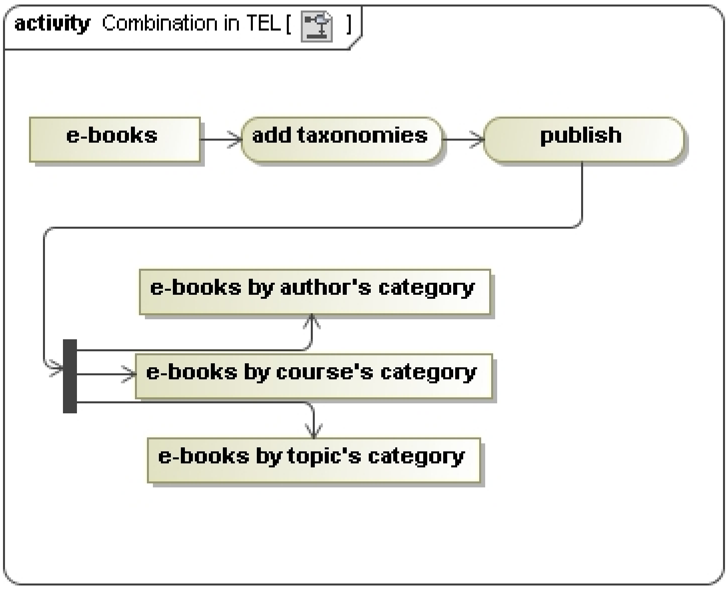

Figure 20. Combination via taxonomies in technology enhanced learning

According to the results which were received in previous works [49], data mining would enable to help the learners who are interested in certain areas by suggesting relevant or complementary courses of which they might not be aware, providing with a personalized registration web page [67]. For the learning providers, they will have the chance to view data of learners and courses from different angles in order to have the full picture, enabling them to make the most profitable decision via targeting the class of users of interest to them and investing more in courses that are highly required by their targeted classes of students [39].

The success of knowledge management projects in such big organizations like universities requires not only interoperability of systems, but consciousness, support and agreements from many departments, top management and every participant.

Knowledge management in Web 2.0

Web 2.0 technologies could play an important role both in technologies enhanced learning and knowledge management. This chapter gives an idea and suggestions for future work in these areas [132].

In the Web 2.0 world knowledge and knowledge management have received a new meaning and dimension. Knowledge is named microknowledge and it is represented in the form of a microcontent object that has at least one unique identity with at least one unique address on the network, and that encapsulates no more than a small number of central ideas [115]. The Web 2.0 tools that are more frequently used in university and enterprise environments nowadays are: weblogs, wikis, social bookmarking, tagging, RSS/Atom syndication, podcasts, search engines, social networks, where the microcontent can be metadata, learning content, information content, instructions, comments, feedbacks [50], [46]. Among the advantages of using the Web 2.0 technologies in the learning process there are [132]:

- facilitated process of knowledge objects creation by learners/educators,
- knowledge objects enhanced by tagging and group use,
- increased frequency of small communication/awareness knowledge objects,
- multiple interventions over a period of time,
- involve multiple learners/educators in the overall intervention,
- reporting tools,
- assessments tied directly to knowledge objects, integration of metrics and community use information to track utility.

The best way to use the most of these advantages and to improve the learning process is to create instructional strategies that will control user learning paths and activities at using all of these different tools [132]. Different instructional strategies can be designed for different learners to personalize their learning activities and learning content and to provide adapted services to them according to their knowledge, personal interests and goals. The IMS Learning design (LD) specification provides a framework within which it is possible to describe the structure of tasks and activities, their assignment to roles, and the workflow of a unit of learning, and also provides a platform-independent notational convention to allow sharing and reuse of these designs [119].

Personalized support for learners becomes even more important, when e.learning takes place in open and dynamic learning and information networks like this based on Web 2.0 technologies. The pedagogical aspect of personalized learning using distributed information in dynamic and heterogeneous learning networks is still an unsolved problem in e-learning research [132].

Now it is the challenge for educators and learning designers to systematically develop new patterns and strategies suitable for personalized learning in a Web 2.0 environment. This makes it necessary to understand the evolving new kinds of learning experiences, and to further enhance and enable them with the right tools, applications and contents [132].

Table 7. Learning activity and activity structures in Web 2.0

<table>
<tr><th>Learning Objectives</th><th>Activities</th><th>Activity Structure</th></tr>
<tr><td>Learning Objective 1: Understand and summarize the problem</td><td>Activity 1: Study MK in Wiki, Blog
Activity 2: Use Podcast for understanding and communication
Activity 3: Search additional MK using tags
Activity 4: Pass PreTest</td><td>Activity Structure 1: Activity 1,2,3,4</td></tr>
<tr><td>Learning Objective 2: Divide and define its main items</td><td>Activity 5: Divide the problem of main items
Activity 6: Describe each item using blog as the personal MK management tool</td><td rowspan="4">Activity Structure 2: Activity 5,6,7,8,9,10,11

Activity Structure 3: Activity 5,6,7,8,9,10,11

Activity Structure 4: Activity 7,8,9,10,11

Activity Structure 5: Activity 9,10,11

Activity Structure 6: Activity 5,6,9,10,11</td></tr>
<tr><td>Learning Objective 3: Prepare analysis of studied MK and create document</td><td>Activity 7: Analyse studied MK and find bottlenecks
Activity 8: Prepare and publish document</td></tr>
<tr><td>Learning Objective 4: Discover solution/s of the problem and evaluate each solution</td><td>Activity 9: Discover and define possible solution/s
Activity 10: Evaluate the solution using social software</td></tr>
<tr><td>Learning Objective 5: Make conclusions</td><td>Activity 11: Make and share conclusions
Activity 12: Pass Test</td></tr>
</table>

Two main roles are described: the role of learner and educator. The learner actively participates in the learning process and the educator monitors and advices the learner. Learning activities and activity structures perform in two environments (Table 7) [132], 126]:

The activities could be arranged in the way present in Table 8 [132]:

Table 8. Web 2.0 and learning environments

Environment	Description
Environment 1	Blog, Wiki, Podcast, Search Engine, Social Network Sites
Environment 2	eLearning System, analyzing and documenting software

This example shows the learning flow of the learner based on her/his performance. Personalized learning paths are defined according to the learner's achievements. Personalization as the key element of the learning process offers possibilities to serve flexible, effective and efficient education, to adjust to various learning conditions and needs. Web 2.0 networks have the potential to support collaborative microknowledge creation, to foster community building and to extend the traditional learning models. Applying learning design concepts to education in Web 2.0 networks led to organizing, controlling and exchanging learner's personal microknowledge [132].

4.4. Conclusions of the 4th chapter

The suggested architecture of KMS and the modelled ICT for knowledge creation, storage/retrieval, transferring and applying were implemented in three different projects. The application of the suggested architecture improved accessibility of wanted knowledge (TEL), reduced 15 different information resources to a single one (EU structural assistance), and improved creation and storage of implicit knowledge (Joint Stock Company ERP).

Furthermore, the process of implementation of these processes showed that the key factors of successful KMS implementations are interoperability and integration of existing systems which are well supported due to the architecture's flexibility.

General conclusions

1. The analysis of current research in the knowledge management field indicates that KM is well integrated on the technical layer but rather loose and weak at the management layer. Current KM systems are often too complex or all-encompassing for smaller companies with limited resources and know-how.
2. The analysis of knowledge management processes specifies that knowledge management mainly consists of the four processes described by Alavi and Leidner, which are knowledge creation, knowledge transfer, knowledge storage/retrieval, knowledge application. Some other authors divided knowledge management into more processes, but most of them either repeat or could be generalized to the four processes.
3. None of the architectures analyzed in this thesis excerpts a knowledge management processes layer. Furthermore, the only architecture that pays attention to knowledge management processes and considers integration with other management disciplines at all is the KM services oriented architecture. However, service orientation has besides its advantages (e.g. flexibility) also its drawbacks (e.g. considerable complexity).

4. The suggested three layers architecture is knowledge management processes centred. These are knowledge creation, storage/retrieval, applying, and transferring. Centring to KM processes improves the integration with other disciplines on the management level. It promotes that experience and research made in the knowledge management field would be used and supported by ICT combining these two fields together to make the system more efficient. Furthermore, KMP-orientation ensures the involvement of implicit knowledge in the system.
5. Application of models from different information and communication technologies for each of the processes makes the system more flexible. In particular it enables a step-by-step implementation or adoption of KM in enterprises, as one can concentrate on one particular process at a time (e.g. the currently most important). Another important implication of the flexibility is the ability of integrating existing information and communication technologies in organizations with a combination of new ICT, taking explicitly KM processes into account. This clearly increases significance and efficiency of a knowledge management system in practice.
6. The suggested architecture of KMS and the conception of ICT for knowledge creation, storage/retrieval, transferring and applying were implemented in three different projects, taking into account their respective requirements. Practical implementations showed the flexibility and adaptability of the architecture especially for small- and medium-sized organizations. The architecture enables to use already existing ICT in organizations by adding new technologies and tools to support or improve the processes. Thus, it requires systems interoperability and keeping standards.

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Appendixes

Appendix 1. Knowledge postfix and prefix ontologies

Naeve described possible knowledge postfixes like knowledge discovery, knowledge base, knowledge architecture, knowledge management, knowledge sharing , etc. by putting links between different conceptions, where rectangle means concept, line with arrow in the end – "kind of", line with diamond in the end – "has", dashed line with arrow – "is a", direct line – "association", and direct line with arrow in the end – "directed-association".

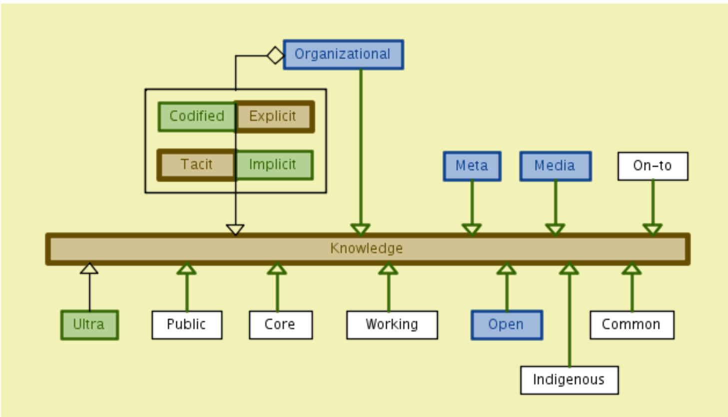

Figure 21. Knowledge prefix ontology [124][1]

[1] Conzilla Context-Map is available online at:

The knowledge prefix ontology. It contains prefixes like organizational knowledge, metaknowledge, media knowledge, etc.

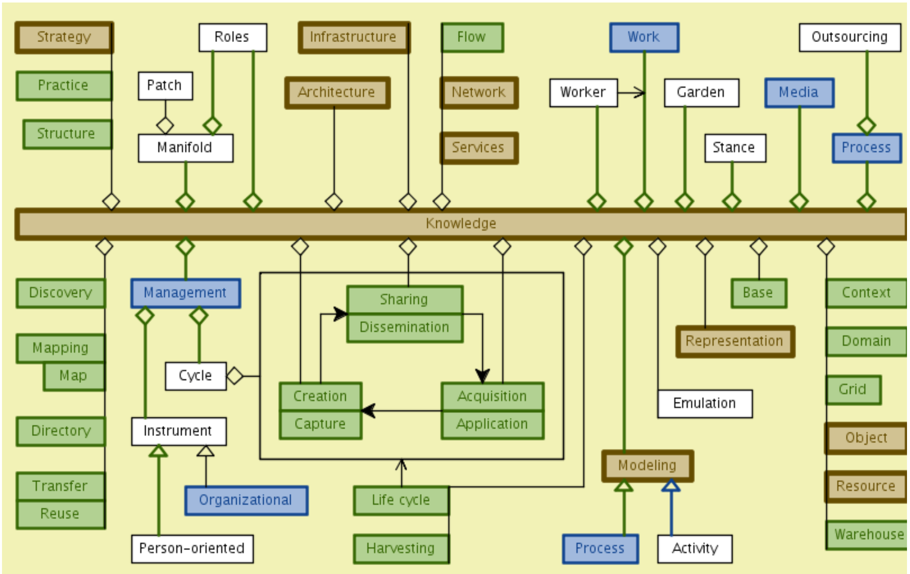

Figure 22. Knowledge postfix ontology [124][2]

http://www.conzilla.org/projects/roadmapping/presentation/CM#4ce9910a83504660 (Accessed on 2008.03.16)

[2] Conzilla Context-Map is available online at: http://www.conzilla.org/projects/roadmapping/presentation/CM#ad65f710a42a716c2 (Accessed on 2008.03.16)

Appendix 2. SECI processes for learning

The different knowledge conversions have been modelled as processes. During the socialization process we respond to challenges and activities by collecting inspiring experiences. During the externalization process they form the input for discussions, which produce articulated concepts. During the combination process, these articulated concepts are connected and combined into conceptual models, and during the internalization process, these conceptual models are reflected upon, which results in increased understanding of the issues involved [74].

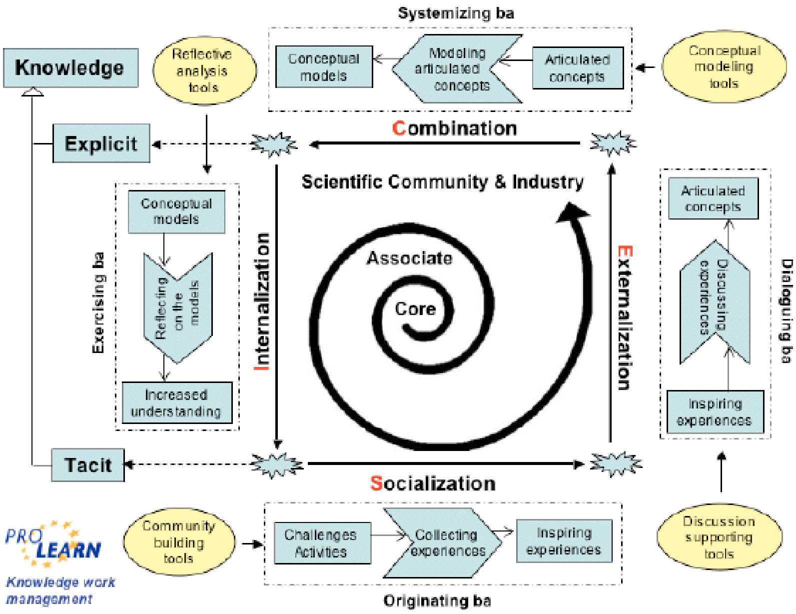

Figure 23. Applying the SECI process framework to *Knowledge work management* could give a classification framework for knowledge-creating types of workplace learning processes [74]

Appendix 3. Knowledge management systems

FlashMeeting was created as discussion supporting tool for learners which main purpose reflect on the collected experiences, which should be articulated [110]. To use a meeting you need to pre-book it (as a registered user) and after you receive a password for the meeting from the FlashMeeting server. The person who booked the meeting invites people who wish to participate by sending the link to the meeting. FlashMeeting is an application based on the Adobe Flash plug in and Flash Media Server [118].

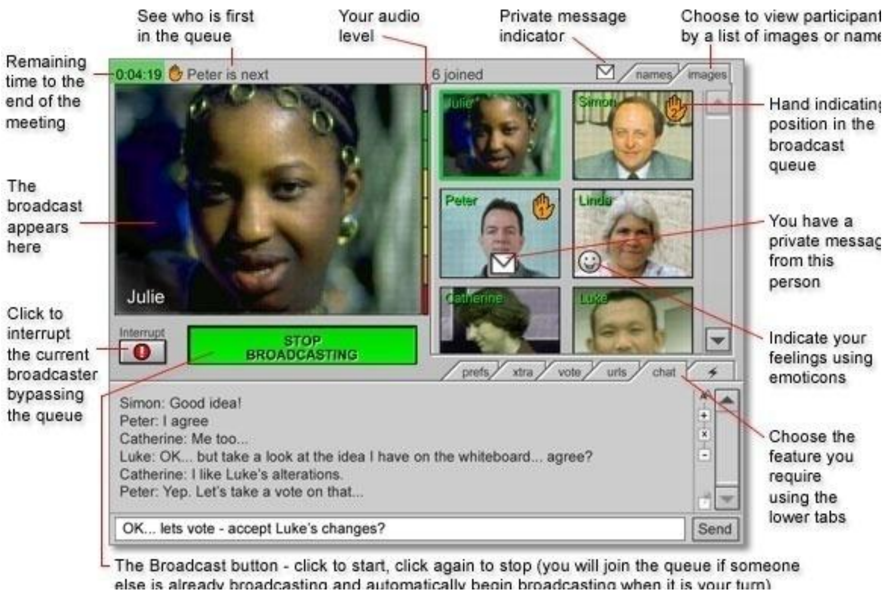

Figure 24. Meeting on FlashMeeting [101]

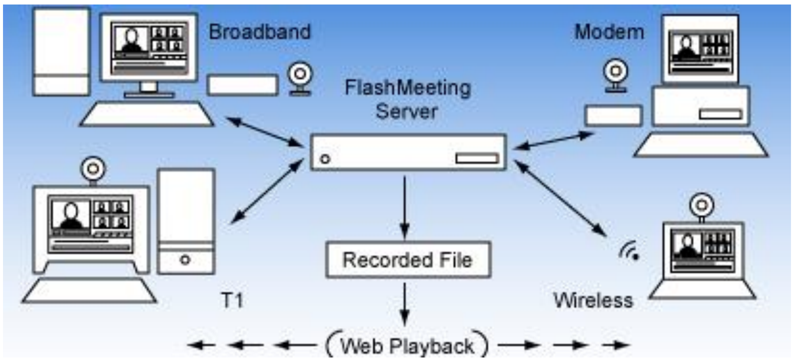

Figure 25. FlashMeeting architecture [101]

Conzilla presents knowledge in terms of specific maps, Context-maps. A Context-map displays nodes and arcs, from now on referred to as concepts and concept-relations, with specific box-forms, icons, arrow-heads, line styles, etc. [124].

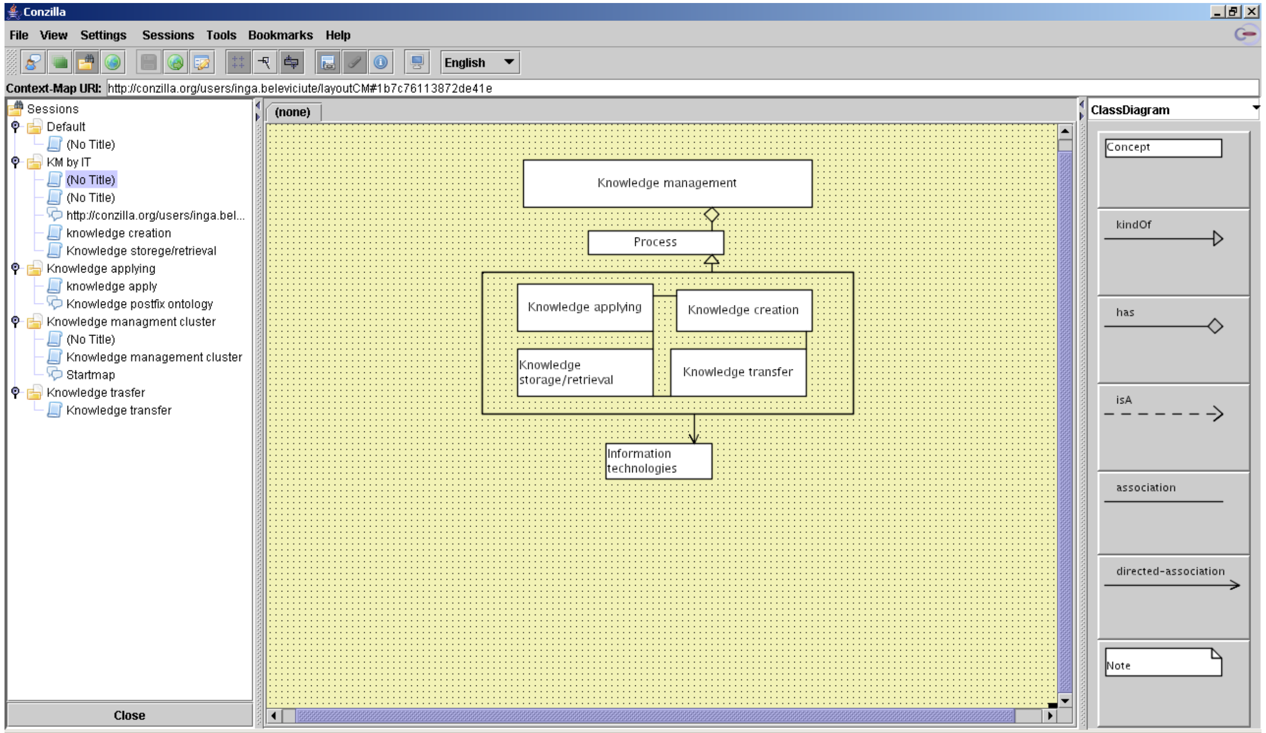

Figure 26. Conceptual map in Conzilla

There is an example of a map with comments of other researcher in red rectangle.

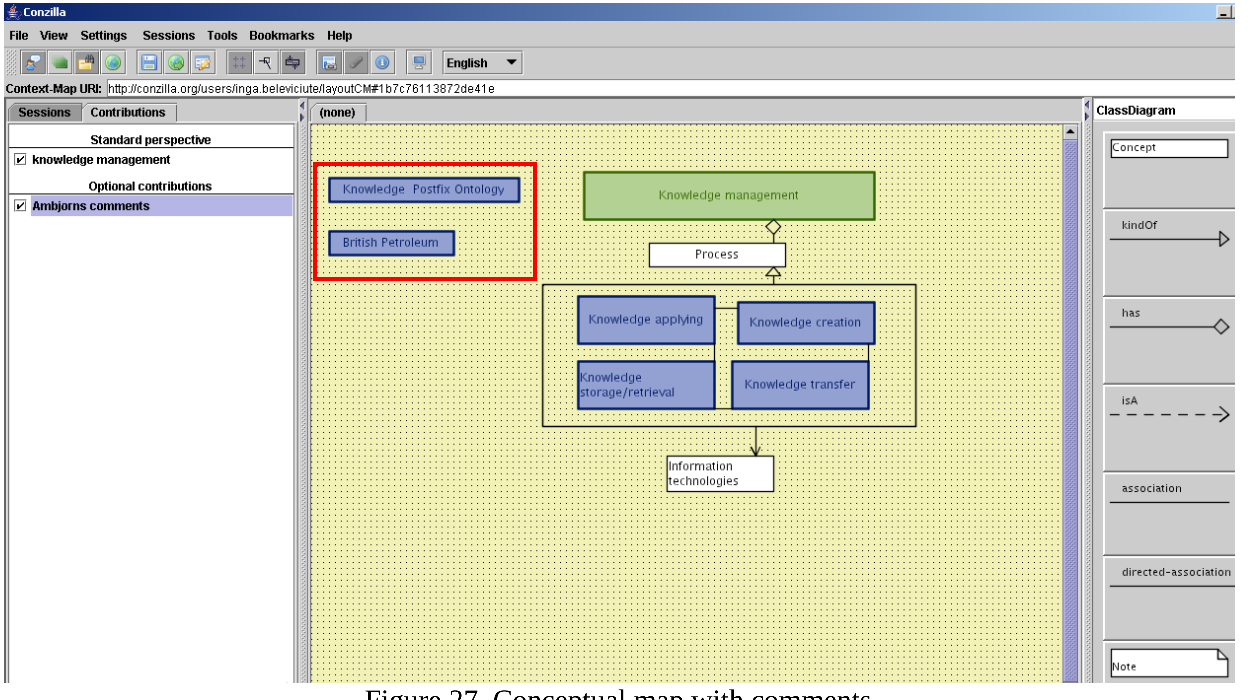

Figure 27. Conceptual map with comments

One of the knowledge management systems is IBM Lotus Discovery System (LDS). Lotus Discovery server contains such components like K-map or taxonomy, spiders, metrics, profiles, etc. [78].

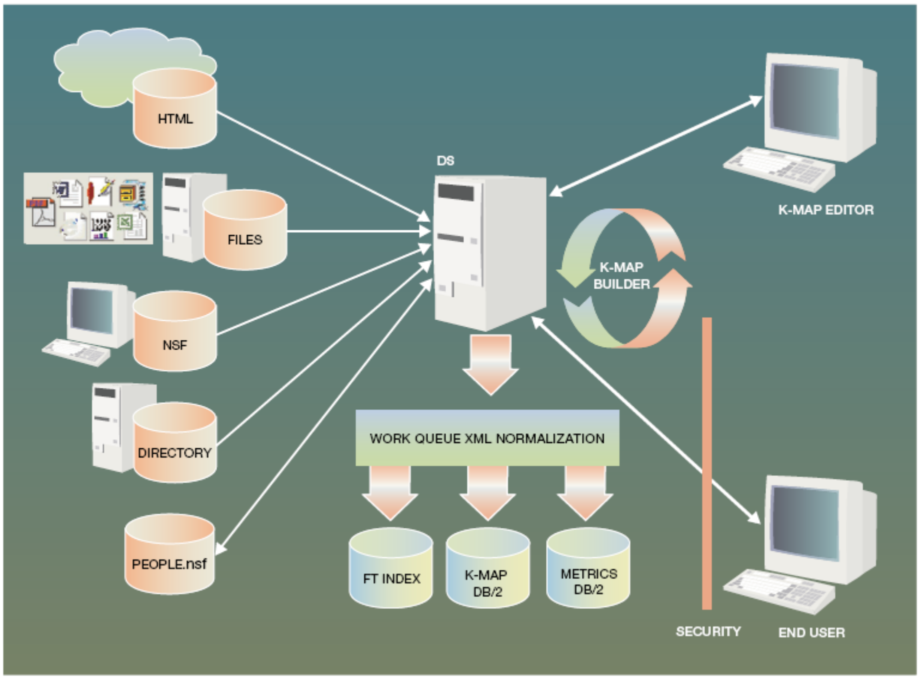

Figure 28. IBM Lotus Discovery system [78]

Appendix 4. Knowledge management system architectures

Applehans, Globe and Laugero [6] suggested six layers of knowledge management system architecture.

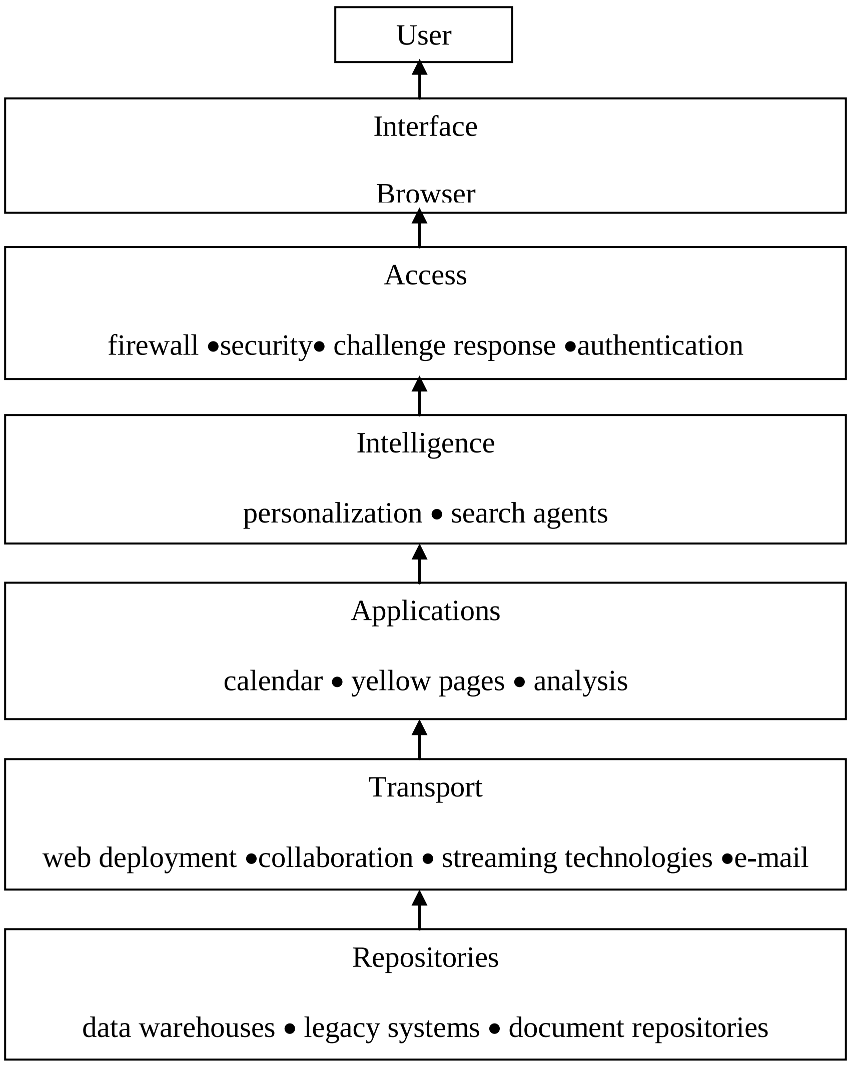

Figure 29. Applehans knowledge management system architecture [6]

Becker, Neumann and Serries present KMS architecture from a metadata point of view [9].

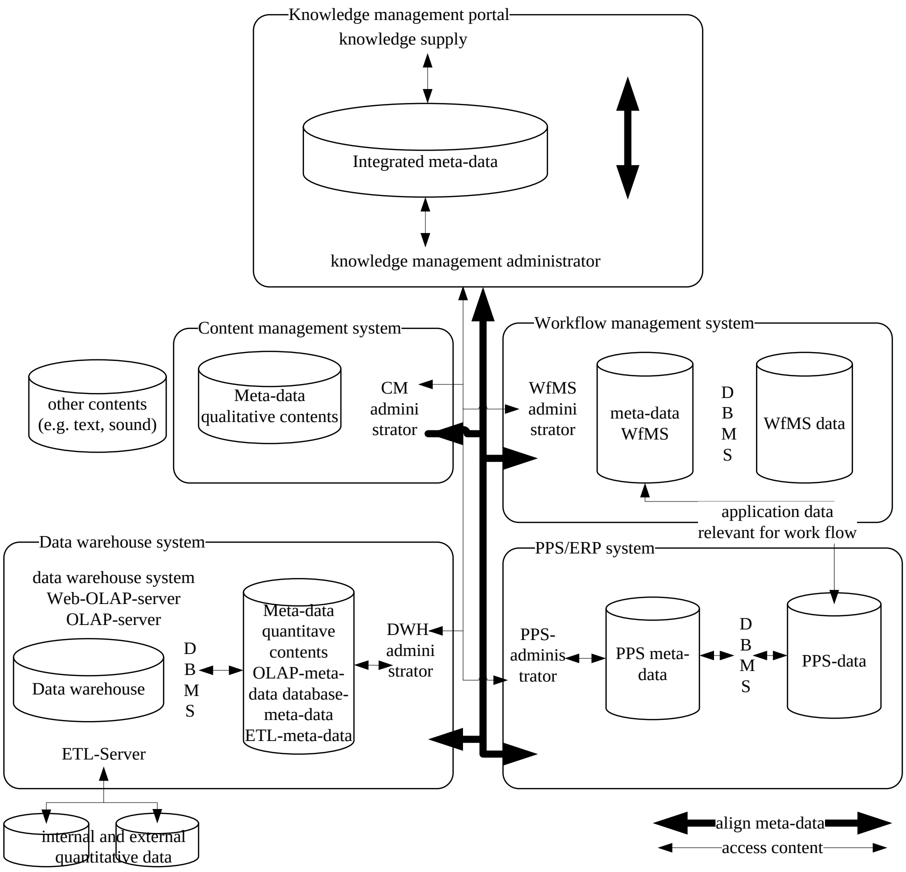

Figure 30. Metadata oriented knowledge management system architecture [9]

Maier used strongest points of existing systems and creatds an “ideal” architecture for centralized knowledge management systems [47], [49]. He extracted six layers (Figure 31. Architecture for centralized knowledge management systems [56], [58]).

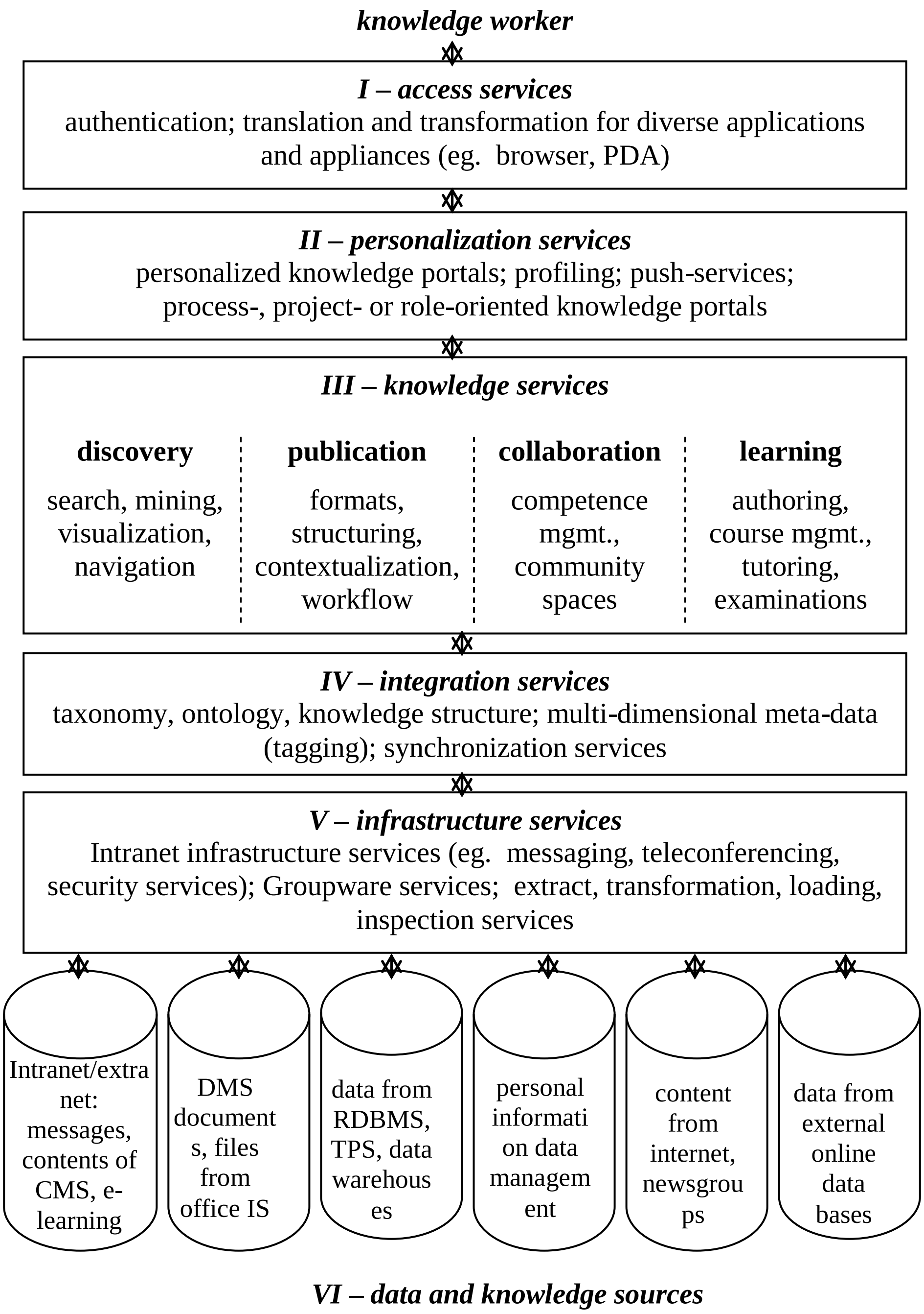
knowledge worker
I – access services
authentication; translation and transformation for diverse applications and appliances (eg. browser, PDA)
II – personalization services
personalized knowledge portals; profiling; push-services; process-, project- or role-oriented knowledge portals
III – knowledge services
discovery
search, mining, visualization, navigation
publication
formats, structuring, contextualization, workflow
collaboration
competence mgmt., community spaces
learning
authoring, course mgmt., tutoring, examinations
IV – integration services
taxonomy, ontology, knowledge structure; multi-dimensional meta-data (tagging); synchronization services
V – infrastructure services
Intranet infrastructure services (eg. messaging, teleconferencing, security services); Groupware services; extract, transformation, loading, inspection services
Intranet/extranet: messages, contents of CMS, e-learning
DMS documents, files from office IS
data from RDBMS, TPS, data warehouses
personal information data management
content from internet, newsgroups
data from external online data bases
VI – data and knowledge sources

Figure 31. Architecture for centralized knowledge management systems [56], [58]

The features of the knowledge management system architecture suggested by Staniszkis [96] are grouped into six principal feature sets where each set contains specific tools.

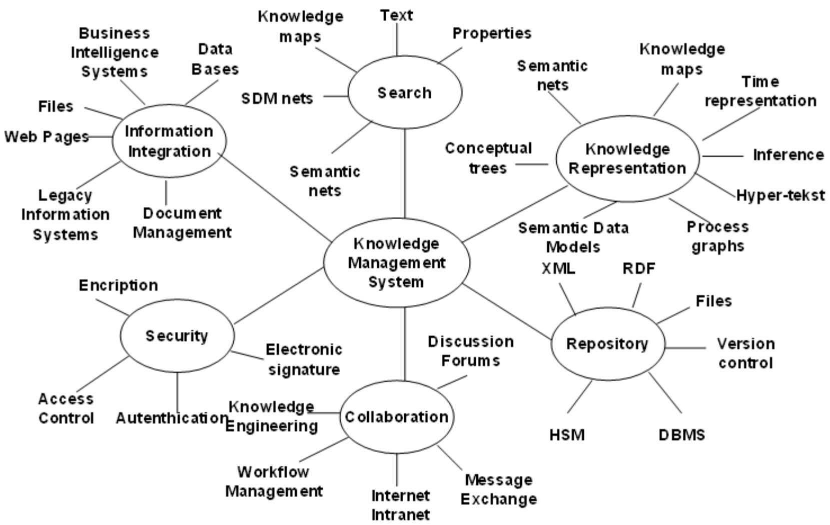

Figure 32. Knowledge management system reference architecture [96]

Abar at al. suggested a knowledge management system architecture based on an agent-based distributed information processing system (ADIPS) [1].

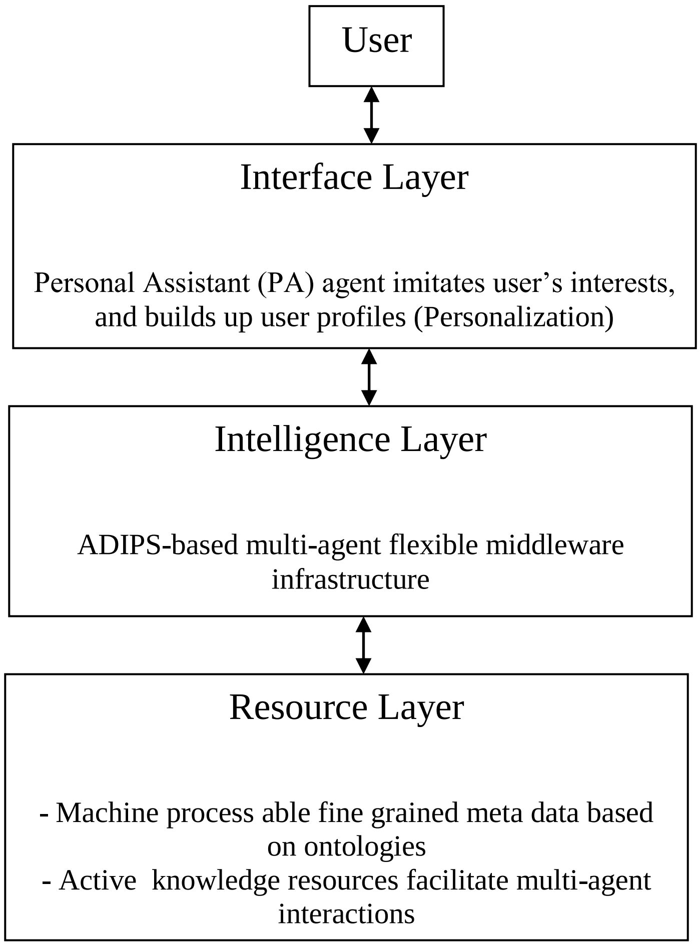

Figure 33. Knowledge management system architecture based on agent-based distributed information processing system

Dzemydienė suggested a componential knowledge management system architecture which consists of a knowledge portal, knowledge components, and a knowledge repository [27].

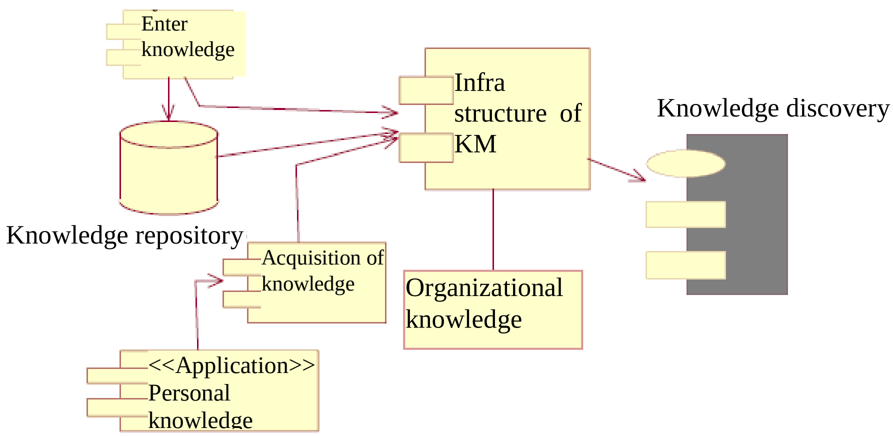

Figure 34. Componential knowledge management system architecture according to Finneran [27], [32]

Woitsch and Karagiannis depicted an overview of the service based KMS architecture.

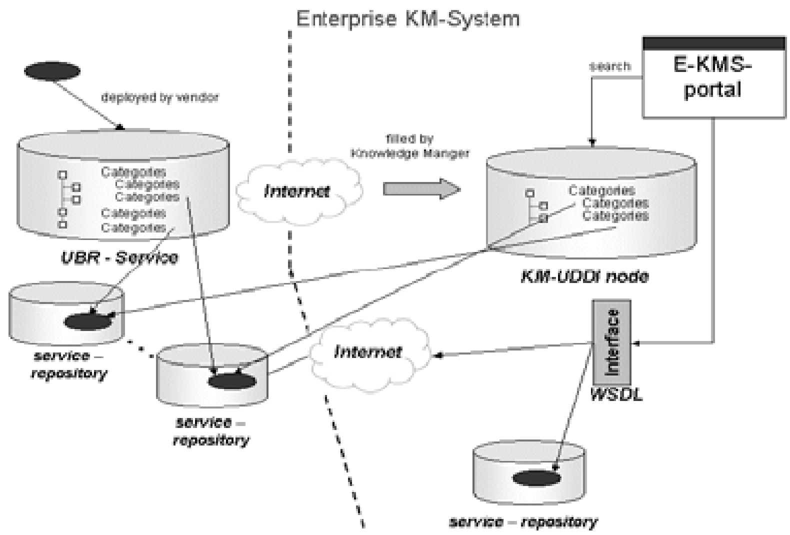

Figure 35. Architecture of service based knowledge management system [108]

British Petroleum's knowledge management approach is encompassed by a simple framework, which describes a learning cycle [18].

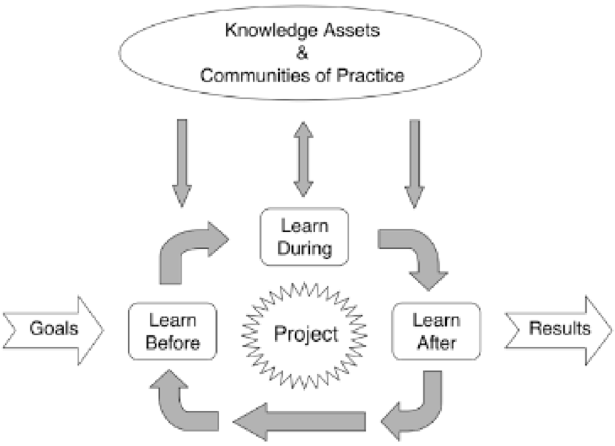

Figure 36. The British Petroleum knowledge management architecture: Learn Before, during and after a project [18]

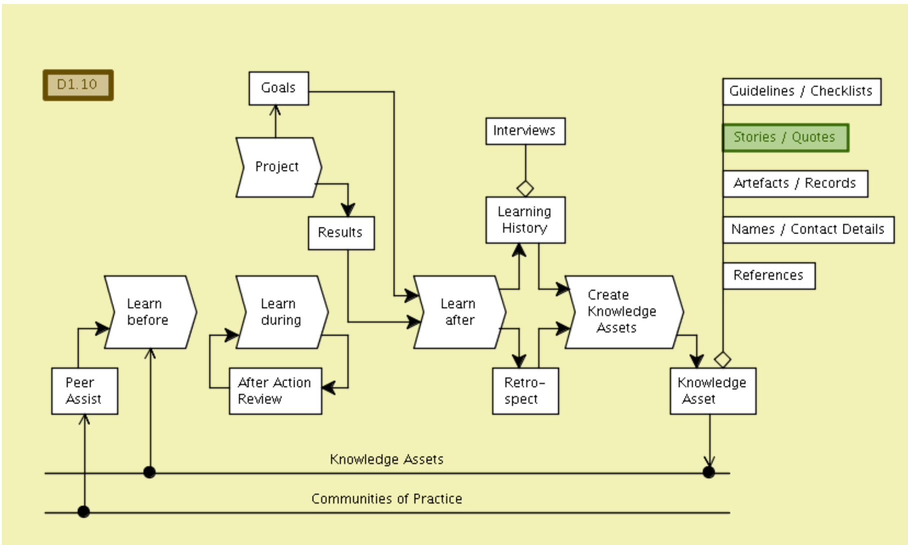

Figure 37. A Conzilla model of the British Petroleum knowledge management process [73]

Appendix 5. Knowledge management implementations in organizations

The main page of the EU structural assistance portal.

Figure 38. Home page of Europe Union structural assistance portal

Collaborative environment eRoom with integrated messenger.

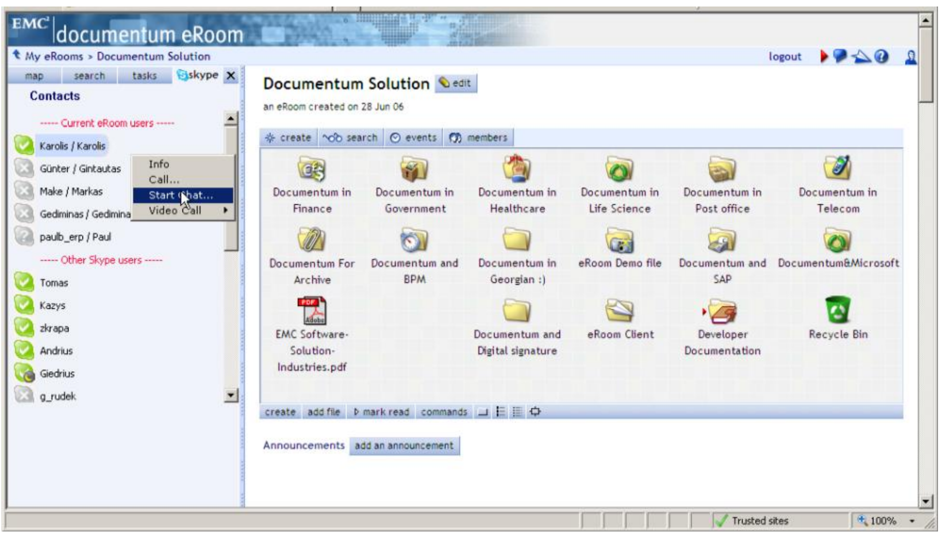

Figure 39. Collaborative environment with integrated messenger

Collected implicit knowledge in the collaboration environment.

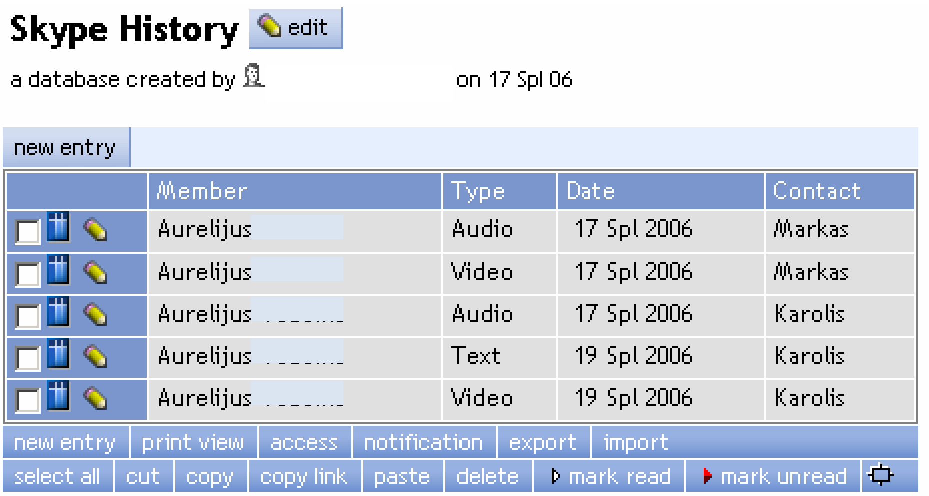

Figure 40. Collected implicit knowledge in the collaboration environment

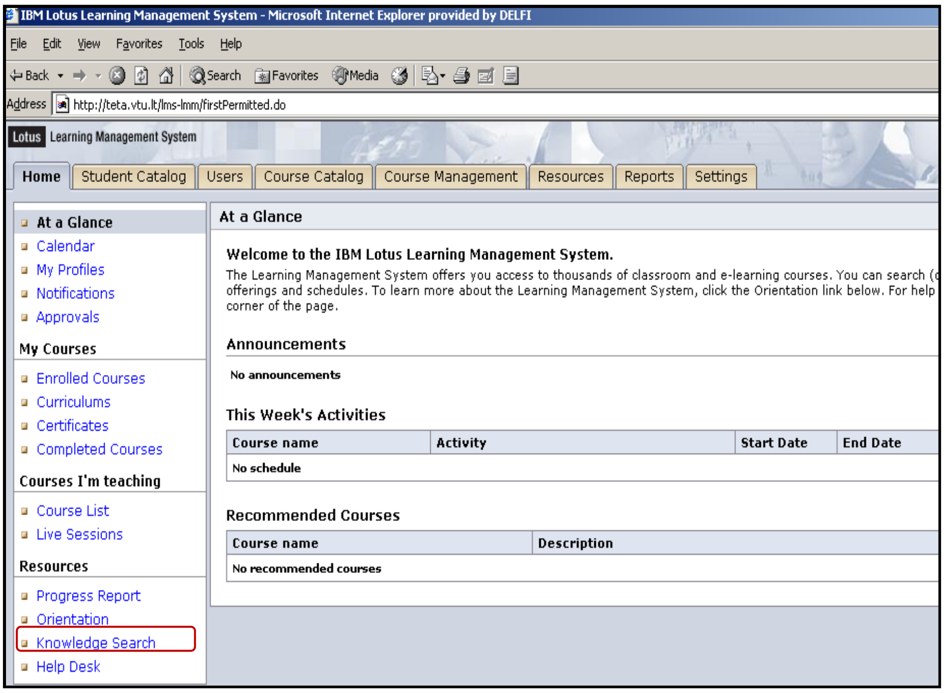

Figure 41. Home page of the learning management system with knowledge search link

Appendix 6. Confirmation letters about practical results

Confirmation letter about practical results from joint stock company "ERP".

Confirmation letter about practical results from the Ministry of Finance of the Republic of Lithuania.