Architecture on Knowledge Management Systems: its presence in the academic literature

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Abstract. Knowledge management allows managing not only the information possessed by people, but also the experiences, judgments, cognitive beliefs adapted and empowered by an individual's mind. The concrete implementation of knowledge management in organizations requires considering diverse views (or approaches), including the technological aspects and their structuration in a software architecture. This paper proposes a Scoping Study based on the following research questions: how many papers associated with knowledge management deal with software architecture? what types of architectures are presented in the papers found? and what information about these architectures are presented in the papers?

Keywords: Knowledge Management, Architecture, KMS

1. Introduction

The changes in organizational practices in the last decades, the incorporation of information technologies, the identification of the importance of the collaborative knowledge building and the attention on the staff turnover that affects some industries, have increased the concern for knowledge management, understood as an emerging instance from the experiences that workers produce in their daily actions, the decisions they make, the interactions with other individuals, etc. Thus, knowledge management is already an indispensable practice for organizations. However, despite the maturity in the awareness of the relevance of knowledge management aspects, it is still difficult to implement a complete process and a Knowledge Management System (KMS) since there have been no significant advances in the research of technological aspects that support the processes and practices, and there is no clarity in the theoretical frameworks regarding the technological architecture to be used. This paper seeks to review the academic literature to identify proposals related to knowledge management architecture in order to contribute to the construction of a conceptual framework and to identify the different types of possible architecture models and what information (and technologies) about these architectures are presented in the papers.

This work presents the concepts of Knowledge (2.1), Knowledge Management (2.2), architecture (2.3) and architecture for KM (2.4). In section 3, it presents the method.

Then, it shows the scoping study (section 4) and the study selection (section 5). Finally, section 6 presents the results and section 7, the conclusions.

2. Background

2.1. Knowledge

Knowledge is part of a hierarchy, called DIKW (see figure 1) proposed by Ackoff [1] constituted by data at the lowest level, information in a next level and knowledge in the third level of the hierarchy; finally, wisdom constitutes the upper level.

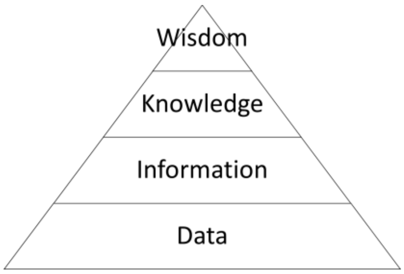

Fig. 1. DIKW Hierarchy

Traditionally, data has been defined as a symbol that has not yet been interpreted [2] or as a simple observation of the state of the world [3]. Information is understood by Davenport and Prusak [4] and Nonaka and Takeuchi [5] as a set of messages; while Bollinger and Smith [6] define it as processed data [7]. Information can be defined as a function of data [8;9], for containing both the data and their context, as specified in Li's Equation:

$$\text{Information} = f\ (\text{Data}) = \text{Data} + \text{Context}_d$$

where f (Data) represents the function that makes sense of Data and returns Information, and Context_d indicates the context of Data.

For Díaz and Millán [10], knowledge is defined as: "the mixture of cognitive and contextualized beliefs, perspectives, judgments, methodologies, information, experiences and expectations made about an object, which are adapted and potentiated by the mind of an individual (knower)". Cornella [11] argues that "the 'metabolization' of information, its conversion into mental structures, generally permanent, leads to the creation of knowledge in our minds," which becomes facts with meaning and structure [12]. In Li's equation is:

$$\text{Knowledge} = p\ (\text{Information}) = \text{Information} + \text{Context}_i + \text{Insight}$$

where p(Information) denotes the processing function that returns Knowledge by making sense of Information under its context, i.e. $Context_i$.

2.2. Knowledge Management

Knowledge management (KM) is a theoretical notion attributed to Etzioni Amitai and defined as "how to create and use knowledge without undermining the organization" [13]. It is an integrated field of multiple disciplines that allow the development of initiatives at different levels of the company [14], with a multidisciplinary approach aimed at a comprehensive and systematic view of information assets [15].

Perez Gonzalez and Darín [16] define it as "an agglutinating process of information management, technology and human resources whose execution is focused on the improvement of high-impact processes, the optimization of knowledge based on these processes and their dissemination throughout the organization".

As regards Knowledge Management there are five views. A view describes the concepts, elements and characteristics of an integrated knowledge management system from the perspective of a set of related concerns. For KM, the views are: a) people (role, responsibilities, etc.); b) organizational aspects (including structure and culture); c) process (or activities); d) knowledge representation and technologies; and e) governance [17;18]. But to identify the technological components without defining a comprehensive architecture is incomplete and difficult to implement. Vasconselos [19] says that "it is essential to derive the technological component in which the main technologies that will be used for the design of the information systems implementation infrastructure are specified".

2.3. Architecture

The origin of software architecture is attributed to Dijkstra, who proposed a structuring for software systems in 1968 [20]. Later, Wirth [21] defined the concept of "stepwise refinement" (the software must be developed considering the decomposition of tasks into subtasks and data into data structures) and DeRemer and Kron [22] introduced the notion of "programming-in-the-large" (design a larger system as a composition of a smaller part). However, these highest-level abstractions as a discipline correspond to the 80's through the work of Mary Shaw [23] and the appearance of "software architecture" as a term by Perry and Wolf [24].

The software architecture of a system is the set of structures needed to reason about the system. It comprises software elements, relationships between them and their properties [25; 26]. For IEEE, software architecture is the fundamental organization of a system, formed by its components, the relationships between them, the context in which they will be implemented, and the principles that guide their design and evolution [27]. The architecture "constitutes a relatively small and intellectually accessible model of how the system is structured and the way in which its components work together" [25].

A survey of the different concepts of software architecture according to various authors can be found in CMU [28], most of which emerged between 1992 and 1995. These concepts are presented in table 1.

Table 1. Definition of software architecture

Author	Definition
Clements et al.	The set of structures needed to reason about the system, which comprises software elements, relations among them, and their properties .
Bass et al.	Structures of the system, which comprise software elements, their externally visible properties, and their relation.
IEEE	Fundamental organization of a system, embodied in its components, their relation and the environment, and the principles governing its design and evolution.
Kruchten [29]	The set of significant decisions about the organization of a software system, the selection of the structural elements and the interfaces in the system, together with their behavior as specified in the collaborations among those elements, the composition of these structural and behavioral elements into progressively larger subsystems, and the architectural style guiding this organization

The notion of software architecture can be used at different levels of abstraction, from a general architecture level of an information system (regardless of its computerization) to the architecture of low-level classes. The Open Group's reference framework [30] presents an enterprise architecture that can be viewed as a set of the following architectures: information architecture, business architecture, technology architecture and application architecture. The last two architectures are more related to this work. The technological architecture describes the hardware, software and communications structure required to support the implementation of information systems [31] and the application architecture defines "the applications required for information management" [32].

This paper uses the technological architecture and the application architecture as the scope of the architecture and explores how both aspects constitute Knowledge Management Systems.

2.4. Architectures for Knowledge Management System

According to Medina García et al. [33], the architectures for Knowledge Management Systems can be divided into two approaches: classical architectures and proprietary architectures. Proprietary architectures are structured with a strong component of agents and are related to proprietary software with their consequent integration and dependency. For Medina et al., classical architectures are considered generic and can be applied to all types of Knowledge Management System and their architectural style is N-Layered, organized by layers that communicate to complete the required functionality; each layer has a well-defined scope and functionality. However, there are architectures that, even if they were generic, might not have an N-Layer architectural style.

Therefore, the following types of architectures can exist: generic N-layer, generic without N-layer (called Non Layer in this paper) and proprietary.

3. Method

This work proposes a Scoping Study (also known as Systematic Mapping Study). It's is a type of Literature Review. While the Systematic Literature Review makes it possible to identify, evaluate and interpret all available research relevant to a particular research question, or topic area, or phenomenon of interest, Systematic Mapping Studies are designed to provide a wide overview of a research area. Their main differences are the depth of the study and the rigorous application of the method and definition of inclusion and exclusion criteria. shows details about the differences.

Scoping studies "aim to map rapidly the key concepts underpinning a research area and the main sources and types of evidence available and can be undertaken as standalone projects in their own right, especially where an area is complex or has not been reviewed comprehensively before" [34]. It is possible to identify at least four common reasons why a scoping study might be undertaken: to examine the extent, range and nature of research activity; to determine the value of undertaking a full systematic review; to summarise and disseminate research findings and to identify research gaps in the existing literature [34].

Arksey & O'Malley [35] propose the following method for the scoping study: identifying the research question; identifying relevant studies; study selection; charting the data; and collating, summarising and reporting the results. The phase of study selection is important because the initial outcome examination from the search protocol may pick up a number of irrelevant studies [35]. This is related to the importance of defining terminology at the beginning of a scoping study, and sometimes reflects some specific difficulties, such as the use of terminology in different countries, different contexts or different countries. The phase of charting describes a technique for synthesising and interpreting qualitative data [36].

4. Scoping Study

4.1. Identifying the research question

This paper is based on the following research questions:

- How many papers associated with knowledge management deal with software architecture?
- What types of architectures are presented in the papers found?
- What information about these architectures are presented in the papers?

4.2. Identifying relevant studies

For the identification of relevant studies, this study includes 3 searches (see table 2). The first searches (Search 1 and Search 2) are conducted on Latin American repositories. The last search (Search 3) is wider in geographic scope and more specific in search terms.

Table 2. Search criteria

Criteria	Search 1	Search 2	Search 3
Source	La Referencia Redalyc SciELO SEDICI SNRD	Idem Search 1	ACM DBLP IEEE Mendeley Springer
Period restriction	2019-2020	2021	2019-2021
Keywords	“gestion del conocimiento”	Idem Search 1	Keyword 1: "knowledge management" architecture Keyword 2: "knowledge architecture"
Keywords in	All	Only Title	All
Inclusion criteria	Publications in Spanish, Portuguese or English		
Exclusion criteria	non-accessible publications publications of authors of this paper		

4.3. Study selection

The search, whose criteria were defined in 4.2, returned 1132 papers. In the detailed analysis of the papers, 3 criteria for the selection of studies were considered:

1. papers that match the term search but use the concept of KM with a different scope than the one presented in this paper were excluded. Generally, these papers refer to topics related to pedagogy;
2. papers related with KM, but which do not make specific reference to any of the views presented in 2.2 were excluded;
3. papers related with KM, but which do not present any technological architecture as presented in 2.3 were excluded.

The results of the searches and the application of the selection criteria presented above yielded the results presented in Table 3.

Table 3. Study selection

	Search 1	Search 2	Search 3
Results	837	130	163
Exclusion criteria 1	499 (60%)	16 (12%)	134 (82%)
Subtotal 1	*338*	*114*	*29*
Exclusion criteria 2	164 (49%)	71 (62%)	1 (3%)
Subtotal 2	*174*	*43*	*28*
Exclusion criteria 3	166 (95 %)	43 (100%)	19 (68%)
Total	*8*	*0*	*6*

As presented in table 3, for search 1 there are 837 results and 60% of them do not match the Knowledge Management topics according to the definitions established in the present work. However, differences are observed between those papers that have the search term in the title (group 1) and those that do not have the search term in the title (group 2): while in the first group only 21% (out of a total of 479) are excluded, in the second group 88% are excluded (out of a total of 358 works). These differences are presented in table 4. Therefore, in search 2, the search criteria are redefined and only papers that include the search term in their title are considered.

Table 4. Study selection. Differences in Search 1.

	Search 1	Group 1	Group 2
Results	837	479	358
Exclusion criteria 1	499 (60%)	423 (88%)	76 (21%)
Subtotal 1	*338*	*56*	*282*
Exclusion criteria 2	164 (49%)	29 (52%)	135 (48%)
Subtotal 2	*174*	*27*	*147*
Exclusion criteria 3	166 (95 %)	26 (95%)	140 (95%)
Total	*8*	*1*	*7*

Comparing search 1 and search 2 and considering the same search criteria (search 1 group 2 and search 2), even considering that search 1 corresponds to 2 years (2019 and 2020) and search 2 to only 1 year (2021), there is a decrease in the number of papers found (from 358 to 130). If the years of the first search are analyzed, a decrease is observed too: for the year 2019 there are 203 papers; for 2020, 155; and finally, for 2021, there are 130.

The papers found related to knowledge management architecture are presented in Table 5 and are detailed in Section 5.

Table 5. Papers found.

Search 1	Search 3	Both
Zavala Zavala (2019)	Tadejko (2020)	Moscoso-Zea et al. (2019)
Jofré et al. (2019)	Liu (2019)	Ruiz et al. (2020)
Moscoso-Zea (2019)	Ting Su et al. (2019)	
Gutierrez Bogota (2020)	Haitao et al. (2020	
Pastrana Cruz (2020)		
Sanchez Valencia (2019)		

4.4. Charting the data

As presented in 2.4., according to Medina García et al. [33], the architectures for Knowledge Management Systems can be divided into two approaches: classical architectures and proprietary architectures. For Medina et al., classical architectures are considered generic and can be applied to all types of Knowledge Management Systems and their architectural style is N-Layered. However, there are architectures which, even if they were generic, might not have an N-Layer architectural style. Therefore, the following types of architectures can exist: generic N-layer, generic without N-layer (called Non Layer in this paper) and proprietary.

Considering the research questions "what types of architectures are presented in the papers found?" and "what information about these architectures is presented in the papers?", this paper aims to identify the following characteristics of each architecture presented:

a. type of architecture: generic N-Layer; generic Non Layer; proprietary;
b. whether it defines components (technologies and applications**)**;
c. whether it presents the relationships between components;
d. whether it presents the relationships between components of the same layer (only for N-Layer architecture)
e. whether it presents the relationships between components of different layers (only for N-Layer architecture)

4.5. Collating, summarising and reporting the results

The data collation, summary and report are presented in 6.

5. Study Selection

This section present details about the findings for each knowledge management architecture in the scoping study.

Zavala Zavala [37] presents a technological integration model of Kerschberg and makes a proposal for a knowledge management software with a component model structured in layers and a computer model for analysis and automation. The proposed layered model preserves the 3 layers proposed by Kerschberg: presentation, knowledge management and information sources. However, it does not present technologies or technological processes associated with the first two layers, reserving the presentation of technology only for the information sources layer.

Jofré et al. [38] defines an architecture organized according to the architecture of De Freitas and Yaber, who classify knowledge management tools according to the activity to which they are associated: knowledge acquisition, discovery and creation, use and development and its dissemination and present architectures of Tiwana, Woods and Sheina and Kerchsberg. None of the architectures presented have a higher level of detail than the high level of architectural definition (i.e. its layers and some tools).

Moscoso-Zea [39] and Moscoso-Zea et al. [40] proposes a framework for knowledge management, presenting the necessary people and processes, Business Intelligence activities (analysis and ETL) and their relationship with Enterprise Architecture, and presents the following technologies: data warehouse, EA repository and a knowledge management system, also including OLTP Databases, OLAP Tools, Educational Data Warehouse and Educational Data Mining. However, it does not propose further details associated with technological architecture.

Gutierrez Bogota [41] proposes a layered architecture: vision, communities, access channels, applications, knowledge repository, infrastructure and enabling environment. It can be observed that some of the layers do not correspond to technological architecture but they are associated with enterprise architecture; in the remaining layers the author does propose any specific technologies.

Pastrana Cruz [42] proposes a knowledge management architecture with layers of information sources, knowledge management and presentation, without defining any specific technologies for each layer.

Ruiz et al. [43] presents a detailed architecture for knowledge management. However, it seems to be a description of processes with some references to the architecture, with identification of some components.

Sanchez Valencia [44] seeks to determine the incidence of ITIL (a set of concepts and best practices for technology service management) in knowledge management in the application support area of an IT consultancy. He presents a web architecture for a knowledge management system, though very basic, defining the need for a metadatabase and a FileSystem.

Tadejko [45] presents a Cognitive Services subsystem in Knowledge Management IT System Architecture as well as Cognitive Services functions in relation to the DIKW Pyramid.

Liu [46] conducted a research work on Knowledge Management Technology of Aerospace Engineering Based on Big Data and shows the Hadoop architecture. Hadoop is a distributed system infrastructure developed by the Apache Foundation and implements a Distributed File System. Liu shows a framework model of Knowledge Management with activities and technologies. Although the framework includes more activities than technologies, some technologies can be found in the creation and storage stage.

Ting Su et al. [47] presents a tool that captures and provides visualization of the usage data of SA artefacts, in particular the usage data of software architecture documents (ADs) called KaitoroCap, a plug-in for the Atlassian Confluence. This tool supports document creation and dynamic restructuring; annotation; exploration path capturing, visualisation and searching. The paper shows a high-level design of KaitoroCap.

Haitao et al. [48] propose an architecture of a pathological Knowledge Management System. It shows a Browser/Server structure with 3 layers: user interface, application layer and storage layer. The application layer mainly includes some modules such as structured pathological knowledge management, semi-structured knowledge management, pathological knowledge network, and pathological knowledge mining modules In turn, the storage layer includes two components: database and knowledge base. The knowledge base "stores knowledge of pathological diagnostic criteria data and clinic pathological diagnosis results obtained by summarizing, filtering and reviewing the data in the pathological database". No integration between components is observed.

6. Results

Each of the papers presented in section 5 is analyzed according to the characteristics indicated in section 4.4. and the results are presented in table 6. The analysis is performed considering the following:

a. type of architecture: generic N-Layer; generic Non Layer; proprietary;
b. whether it defines components (technologies and applications);
c. whether it presents the relationships between components;
d. whether it presents the relationships between components of the same layer (only for N-Layer architecture)
e. whether it presents the relationships between components of different layers (only for N-Layer architecture)

Table 6. Results

Model	A	b	c	d	e
Zavala-Zavala	Generic N-Layer	Yes	Yes	No	No
Jofré et al.	Generic N-Layer	Yes	Yes	Yes	No
Moscoso-Zea	Generic Non Layer	Yes	Yes	N/A	N/A
Moscoso-Zea et al.	Generic Non Layer	Yes	Yes	N/A	N/A
Gutierrez Bogotá	Generic N-Layer	Yes	No	No	No
Pastrana Cruz	Generic N-Layer	No	No	No	No
Ruiz et al.	Generic N-Layer	Yes	Yes	Yes	Yes
Sanchez Valencia	Generic N-Layer	Yes	No	No	No
Tadejko	Generic N-Layer	Yes	Yes	Yes	Yes
Liu	Generic N-Layer	Yes	Yes	Yes	Yes
Ting Su et al.	Propietary	Yes	Yes	N/A	N/A

Haitao et al.	Generic N-Layer	Yes	Yes	No	No

Although the Moscoso-Zea architectures are considered in this paper, they are higher level architectures (Enterprise Architecture Software), even though they present some proposals that could be used in the architecture for Knowledge Management System. Similarly, Gutierrez Bogota's architecture is also an Enterprise Architecture and proposes layers associated with the business aspect and others linked to knowledge and software. Ting Su especially analyzes a proprietary architecture of a software called KaitoroCap.

The remaining works, oriented to generic architectures, present a layered architecture. This is related to Medina García's statement regarding the relationship between generic architectures and their presentation with a layers style.

The architectures of Zavala-Zavala, Jofré and Haitao are based on Kerchsberg's proposals and consider the traditional layers of software production: presentation layer, knowledge management layer (similar to the logical layer or software business layer) and data source layer. The models of Pastrana Cruz and Sanchez Valencia present their architectures with these same layers.

The proposals of Ruiz, Liu and Tadejko are very different from those mentioned above. Ruiz and Liu present architectures based on the different knowledge management activities, although they also consider them in a layered format and propose some specific applications, while Tadejko proposes an architecture based on the constructivist vision of knowledge and the DIKW pyramid.

7. Conclusions

The architecture of knowledge management is a poorly investigated topic in the bibliography of knowledge management in the sources consulted in this work. In future works, it is planned to carry out a wide search (like those carried out in searches 1 and 2) in the sources used in search 3 (non-Latin American repositories), which will involve an analysis of about 800 papers.

In the works found, the architectures can be categorized as proprietary or generic and can be observed with (or without) the application of the layered architectural pattern. Most of the knowledge management architectures found are layered architectures, with 3 styles for defining the layers: the first is a traditional way associated with software production and based on Kerschberg's architectures (presentation, knowledge management or logical layer and data layer); the second, defines one layer for each knowledge management activities; and, the last associated each layer with the levels of the DIKW pyramid.

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