Study of the Diagnosis of Knowledge Management in Software Development Companies

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Abstract

Knowledge management (KM) is a concept defined by several authors over the years, who agree that it is a process by which organizations discover, use, and maintain knowledge with the idea of aligning it with business strategies to gain competitive advantage. The importance of diagnosing knowledge management lies in understanding what the starting point is and what level of maturity is to be reached, to obtain advantages in economic terms. According to several authors, there is a direct relationship between knowledge and the economic development of industries. To establish the state of the art of KM measurement in software development companies, a systematic mapping study (SMS) is developed. This allows us to systematize the empirical evidence of contributions and types of research that address the diagnosis of knowledge management in software development companies. Then, an analysis and conclusion are made to determine the degree of maturity of these concepts. Finally, future lines of research are proposed.

Keywords

Knowledge management, Measurement and Diagnosis, State of the art, systematic mapping study.

1. Introduction

The aim of this article is to address Knowledge Management in terms of how it is diagnosed, and its scope is limited to the software development industries. In order to understand the progress made in the field, a systematic mapping of the literature in digital repositories is carried out, and based on its results, the articles that relate to the diagnosis of Knowledge Management are analyzed.

This article presents fundamental concepts such as the definition of data, its relationship with knowledge, and how it is managed, measured, and diagnosed 2. Subsequently, it delves into the importance of measuring knowledge by conducting systematic search mappings to know the level of maturity or uniformity found in the diagnostic activities of Knowledge Management 3. An analysis of the results is then proposed 4 and finally conclusions and future lines of research are presented 5.

2. Knowledge

2.1. Data and information

A data is a symbolic representation, either by numbers, letters, algorithms, etc., of a quantitative or qualitative attribute or variable. They describe events but do not in themselves constitute information; it is the processing of the data that provides it.

Unlike data, information has meaning, i.e. relevance and purpose, as data becomes information when its creator adds meaning, relationship and/or conclusions to it.

The notions of data and information were incorporated in the so-called "DIKW Hierarchy" or "Knowledge Pyramid" presented by Ackoff [1] in which it is based on a chain of hierarchy in which each concept adds value to the previous one and by The easy interpretation is represented graphically as a triangle as shown in Figure 1.

This hierarchy has data as its base element, while at a higher level, it has information, then knowledge, and at the top level wisdom.

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Figure 1: DIKW hierarchy

2.2. Knowledge

Regarding the definition of knowledge, Nonaka and Takeuchi [2] state that knowledge can be either tacit or explicit. Tacit knowledge is difficult to formalize, express, and share; it is very personal, subjective, and derived from experience. Explicit knowledge, on the other hand, can be easily expressed, and formalized, and is acquired through formal methods of study.

On the other hand, knowledge makes it possible to generate a vision of understanding of the environment, according to Rueda [3], an aspect that makes sense from a basic point of view. From an advanced aspect, one can agree with the segregation provided by Wiig [4] in which knowledge can be "public" if it is readily available to anyone, "shared" if it is communicated through language and representations, and "personal" if it is tacit in a person.

Gibbs [5] declares knowledge as any judgment, procedure, or object that can be owned (patent or publication) and become an economic resource or a commodity in the market. In conclusion, it can be said that knowledge is the combination of various factors that are consolidated by the individual and characterized by how it is communicated or learned.

2.3. Knowledge management

The concept of management can be understood as the activity of interacting with the areas of an Entity such as technology, compliance, audit, product, cybersecurity, legal, and human resources, among others. This activity perceives an objective that is possible by correctly managing the resources needed to achieve it. The management activity requires knowledge of how to achieve the objectives.

Nonaka and Takeuchi [2] state that knowledge can be tacit or explicit. The former is difficult to formalize, express, and share, very personal, subjective, and derived from experience. Explicit knowledge is knowledge that can be expressed, formalized, and easily acquired through formal methods of study.

The authors state that knowledge can be tacit or explicit. That knowledge that is difficult to formalize, express, and share, that is very personal, subjective, and derived from experience, is tacit. Explicit knowledge is knowledge that can be easily expressed, formalized, and acquired through formal methods of study.

The SECI model is based on these concepts, where it is classified into four modes of conversion (Socialisation, Externalisation, Combination, and Internalisation). It is a dynamic process where knowledge is exchanged and transformed.

The socialization process (tacit to tacit) is the exchange of knowledge through social interactions.

The externalization process (tacit to explicit) is when knowledge is formalized. On the other hand, the combination process (explicit to explicit) recombines knowledge in a new way. As for the internalization process, individual experiences are converted or integrated into the mental models of each individual.

Knowledge Management (KM) is a concept defined by several authors over the years, in which they agree that it is a process by which organizations discover, use, and maintain knowledge with the idea of aligning it with business strategies to obtain competitive advantages, according to Bueno [6].

The company's ability to create new knowledge, disseminate it throughout the organization, and incorporate it into business processes, products, services, and systems is encompassed as KM according to Nonaka and Takeuchi's definitions [2].

The knowledge management lifecycle is an area that deserves attention as it deals with one of the most important assets of a company, knowledge. Obtaining a survey of an organization's current situation allows stakeholders to understand the current state and to measure possible progress.

2.4. Measurement and evaluation

The concept of "measuring" refers to comparing a quantity with its respective unit, to know how many times the latter is contained in the former. It also refers to the action of comparing something non-material with something else. Gutiérrez [7] defines measuring as the process by which a number is assigned to a property or phenomenon to compare it, necessarily involving four systems: the object to be measured; the measurement system or instrument; the comparison system, which is defined as the unit; and the operator who performs the measurement.

Evaluation is a process used to systematically determine the merit, worth, intellectual or physical capacity of someone based on certain criteria with respect to a set of standards. According to the RAE, it refers to the action of indicating the value of something, estimating, appreciating, or calculating its worth. It is also defined as the estimation of students' knowledge, skills, and performance.

Evaluate and measure have been taken as synonymous terms, as they indicate that measurement instruments can evaluate what is measured, with the researcher evaluating the scores obtained on the instrument.

2.5. Diagnosis

Diagnosis is a measurement and/or analysis to assess a situation and its trends, allowing to determine "what is happening". It is a dynamic measurement that changes as variables change and depends on factors such as the observer, the methodology, and the quality of the measurement instruments.

Concerning the concept of "diagnosing", refers to the action of collecting and analyzing data to assess problems of various kinds. The diagnosis of knowledge management seeks to establish the real state of the company concerning knowledge and forms part of the first stage of the KM process according to Peluffo and Catalán [8]. Therefore, the diagnosis makes it possible to identify how knowledge is used, whether it is retained, and how it circulates.

When reference is made to the diagnosis of knowledge, it is synonymous with asking "how much is known", so to answer it is necessary to determine the state in which the KM is in terms of knowledge and its management such as technology, people, culture or processes [9].

The importance of diagnosing knowledge management lies in understanding what the starting point is and what level of maturity is to be reached, to obtain advantages in economic terms. According to several authors such as Druker [10] and Bueno [6], there is a direct relationship between knowledge and the economic development of industries.

Starting from the premise that knowledge is an intangible asset, managing and diagnosing it properly can be a complicated task as it is necessary to be able to perceive it, establish its value, and develop strategies for its measurement. This is why the challenge of diagnosing knowledge presents itself.

Table 1 summarises a comparison between the concepts of measurement and evaluation.

Table 1
Comparison between measurement and evaluation.

Measurement	Evaluation
Quantifying a result	Makes value judgements
Compare results	It includes measurement as part of a process.
Quantify according to the data obtained	Quantify and qualify.

3. Systematic mapping of the literature

This section presents a systematic mapping of the literature (Systematic Mapping Studies or SMS) to discover the contributions that exist in relation to the diagnosis applied to knowledge management in the software industries. To conduct the SMS, the guidelines proposed by Kitchenham [11] were followed.

This SMS aims to answer the following research questions:

- **Q1.** Which discipline does the article refer to?
- **Q2.** What is the contribution related to the diagnosis of knowledge management in software industries?
- **Q3.** What type of research is presented in the articles?

The scope of the systematic mapping is between January 2017 and November 2023. In addition, the search strings and search engines used are as follows:

- **Search strings:** ("Knowledge Management") AND ("Diagnosis") OR ("Metrics") OR ("Software Factory") OR ("Measurement") OR ("Evaluation") OR ("Control").
- **Search engines:** ACM Digital Library, Springer and BibDigital. The following inclusion and exclusion criteria are specified:
  - **Includes:** Articles written in the academic university environment, written in Spanish and English. In the case of duplicate articles, the most complete and the most recent will be taken.
  - **Exclusion:** Articles that are not accessible for reading, as well as slide presentations (MS PowerPoint) and informal documentation.

For each of the research questions, it has been related to dimensions and categories according to table 2:

Table 2
Research questions associated with dimensions by categories.

Dimension/RQ	Categories
Discipline (RQI1)	Medicine, sociology, technology, education, and others.
Input (RQI2)	Metrics, tools, model, methodology or process, and other.
Types of research (RQI3)	Evaluation, philosophical, proposed solution, validation, personal experience, opinion.

The categories corresponding to “Discipline” have been defined before the execution of the SMS, selecting areas of study with a higher level of abstraction. Regarding the categories of “Contributions”, comes from the proposal presented at CoNaIISI 2021 - 9th Congress (page 356), and “Types of Research” arises according to the classification proposed by Wieringa [12].

The study selection process consisted of the following steps: 1) search the defined sources by applying the string in the title and/or abstract, 2) eliminate duplicate articles, 3) apply the inclusion and exclusion criteria in the title, abstract, and keywords, 4) apply the inclusion and exclusion criteria to the full

text. This process allowed the selection of primary studies that were analysed to answer the research questions (RQs) formulated.

The number of articles selected in each of the databases is presented in Table 3. They are classified according to Panizzi's proposal[13] into relevant articles, articles not considered, and primary articles. The meaning of this classification is explained below:

- **Relevant articles:** Are those found and selected from the initial search results that contain the search terms in the abstract, introduction, keywords, or title.
- **Articles not considered:** These are the articles resulting from the search that meet the inclusion/exclusion criteria and after reading them are not considered suitable for the research.
- **Primary articles:** These are articles that have been read in their entirety and are considered suitable for research because they meet the inclusion criteria.

Table 3
Database and selected articles for each stage.

Repository	Relevant items	Not considered	Primary items
Springer	13	10	13
ACM Digital Library	123	108	5
BibDigital	9	1	8
Total	**145**	**119**	**26**

The number of articles found was 145 (relevant articles) of which the following clarifications can be made:

- Of the total number of relevant articles in the Springer repository, i.e. obtained automatically from the search string, 9 of them have not been considered because they are inaccessible for full reading (exclusion criterion), and 1 of them does not answer the research questions.
- As for the ACM Digital Library, of the 123 relevant articles, 44 were not considered because they were not accessible documents for reading. On the other hand, 3 of them are slide presentations and 61 do not correspond to quality control and were therefore excluded. In conclusion, 5 primary articles were obtained.
- Of the total number of relevant articles in the BibDigital repository, i.e. obtained automatically from the search string, 1 of them does not correspond to the research, while the remaining 8 have been defined as primary articles.

In conclusion, the total number of articles not considered was 119 and the number of primary articles resulted in a total of 26 articles. The following section emphasizes the results obtained with the implementation of the SMS.

4. Result

The research questions are answered based on the articles obtained:

4.1. RQI1: Which discipline does the article refer to?

To answer this question, the main articles have been categorized according to the subject matter addressed by the authors.

In conclusion, the total number of articles not considered was 119 and the number of primary articles resulted in a total of 26 articles. In the following section, emphasis is placed on the results obtained from the execution of the SMS. In conclusion, it is mentioned that the largest number of articles are

associated with the field of education and in second place those referring to medicine and technology, as shown in Figure 2.

From reading the articles one finds this relationship since, in educational terms, knowledge management is a closely related concept, while for the discipline of medicine, moving from tacit to explicit knowledge, and developing expert systems is a challenge which in turn is in high demand in the health system. In terms of technology, knowledge management is developed for knowledge to co-exist in industry.

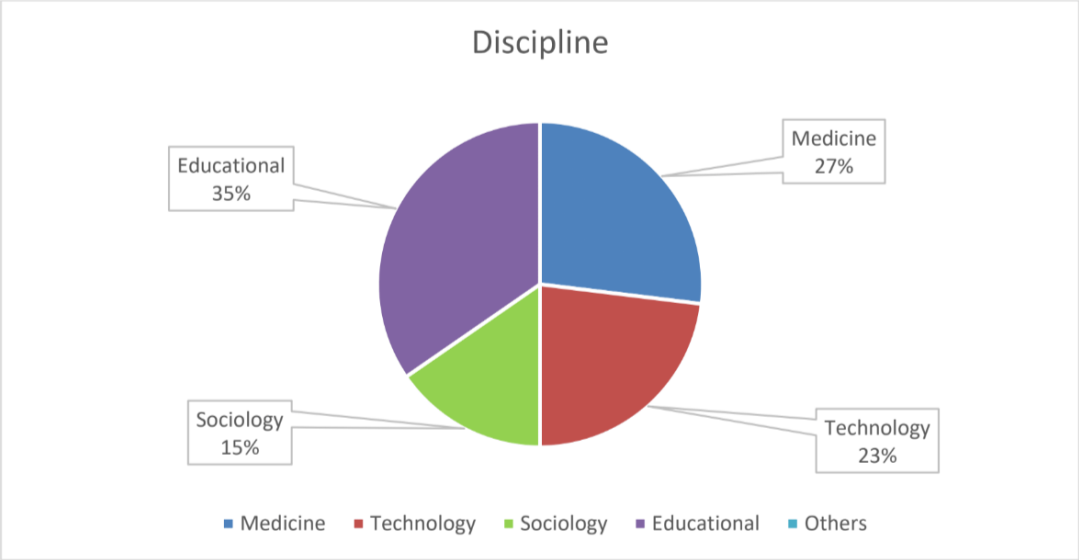

Figure 2: Analysis of results of research question 1.

However, while there is work that goes into QA in general, there is not yet an advanced level of maturity as far as the software industries are concerned.

4.2. RQ2: What is the contribution related to the diagnosis of knowledge management in software industries?

The different types of contributions to Knowledge Management are shown in Figure 3. The largest number of contributions are methodological with a percentage distribution of 35%, however, contributions such as metrics (30%) and processes (26%) are distributed in equal proportions.

From reading the main articles it can be concluded that in terms of knowledge management, rather than a tool to accompany the knowledge management process, the emphasis is on how to do it and how to measure it.

4.3. RQ3: What kind of research is presented in the articles?

The different types of research in Knowledge Management are shown in Figure 4. The largest number of research are evaluations (50%) and solution proposals (29%) with similar percentage distributions. No research in the form of opinion or personal experience was identified.

The conclusion from this research question and from reading the primary articles is that proper quality control is sought through solutions and not so much through the development of articles based on experiences and opinions.

4.4. Analysis of the findings

From the analysis carried out from the results obtained, a diversity of contributions can be identified (tools, processes, methodologies, etc.), however, there is no solution proposal applied to more than

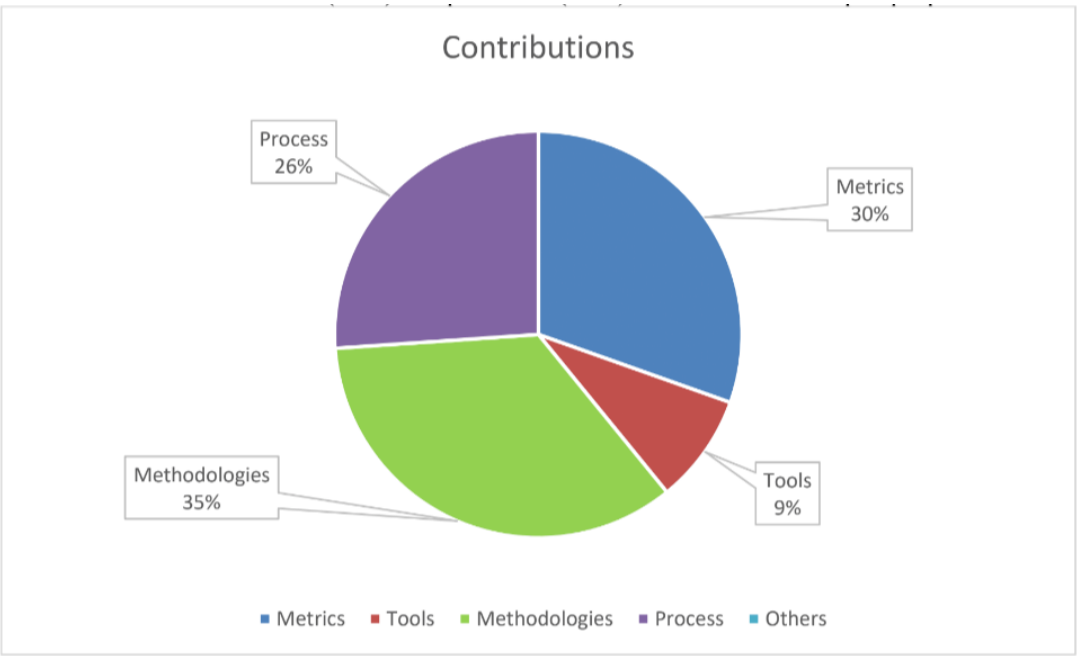

Figure 3: Analysis of results of research question 2.

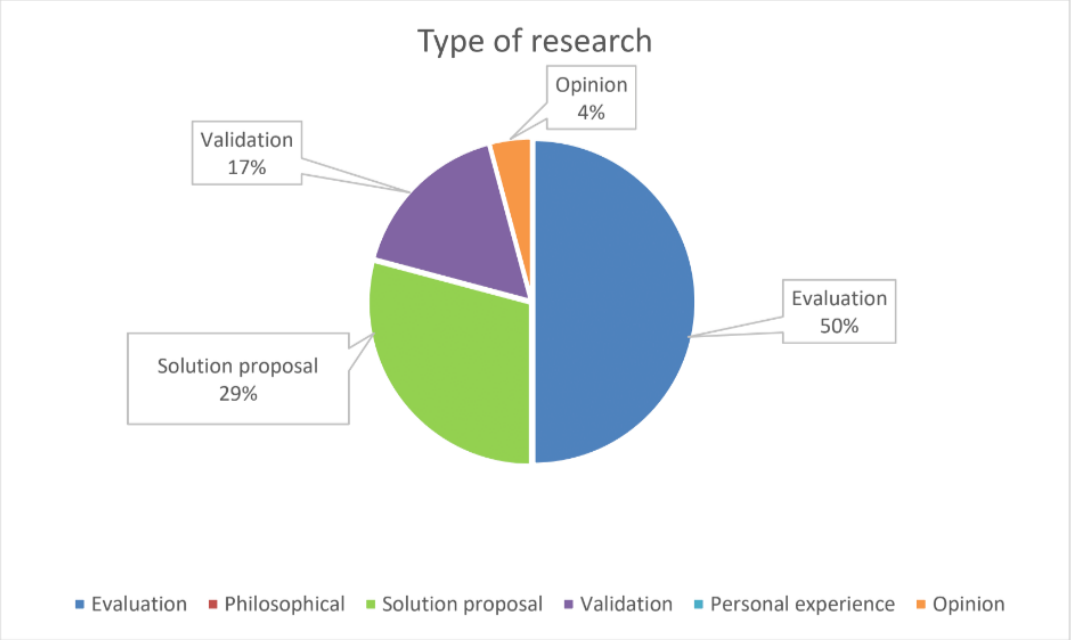

Figure 4: Analysis of results of research question 3.

one main article. It should be noted that the "Nonaka and Takeuchi SECI spiral model" [2] is the main methodology in general used to refer to knowledge management.

On the other hand, a large number of articles are based on non-systematic literature reviews in virtual repositories. Furthermore, articles in the field of medicine based on knowledge management diagnosis can be extrapolated to the software industry.

In summary, although various contributions based on tools, processes, and methodologies are identified, it is detected that there is no advanced level of maturity in terms of how to diagnose knowledge management in software industries, presenting a conceptual gap, making it necessary to minimize through the application of a model.

5. Conclusions and future lines of research

A systematic mapping of the literature was presented to analyze the state of the art of KM diagnosis. From the first set of 119 articles, 26 primary studies resulting from research in Springer, ACM, and BibDigital between January 2017 and November 2023 were selected. Following the analysis of the primary studies, it is concluded that:

- It can be mentioned that most articles are associated with the field of education and secondly with medicine and technology. However, it is important to mention that although there are papers that go into QA aspects in general, there is not yet an advanced level of maturity in terms of software industries.
- Methodologies are the main input for Knowledge Management in the primary studies, however, similar proportions of inputs such as metrics and processes are detected.
- Research of the solution proposal type predominates over the rest. No significant material was found on personal experiences, philosophy or opinions.

On the other hand, although there is no advanced level of maturity regarding the diagnosis of knowledge management in software industries, documents such as "Experience Report on Developing an Ontology-Based Approach for Knowledge Management in Software Testing" (ACM article 5) and "Diagnosis on knowledge management to identify the effect on productivity of footwear companies in Barrio Restrepo" (BibDigital article 1), serve as a starting point to develop aspects related to the diagnosis, as they offer guidelines. based on surveys and interviews to measure and define scope.

The importance of diagnosing knowledge management lies in understanding what the starting point is and what level of maturity it is intended to reach, to obtain advantages in economic terms for companies. This aspect is consolidated as key for the development of companies, in this sense, demanding an increasing demand for models on how to improve the effectiveness of its measurement.

5.1. Future lines of research

A number of gaps became evident since the methodologies, processes, and tools that address Knowledge Management do not focus on how to diagnose it.

In view of the above, and as future work, we will continue to develop a model applicable to the diagnosis of Knowledge Management in software development companies, taking the applicable contributions from the primary articles. On the other hand, since a diagnosis requires going deeper into maturity levels, we will take as a reference the contributions mentioned in the article “Key technology area descriptors in a knowledge management maturity model” by Straccia and Pollo-Cattaneo [14] in which the G-KMMM, Nutresa, Ruta N Corporation, and De Freitas models are mentioned, and descriptors for these subareas for each maturity level and a questionnaire to evaluate each descriptor are proposed.

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