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KNOWLEDGE MANAGEMENT IN DESIGN: A MULTIDISCIPLINARY SURVEY

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ABSTRACT
The reality of knowledge management (KM) in companies joins in a multiplicity of ends and situations. In the scientific literature, KM seems to appear as a sort of a more or less unified and more or less generative "field of research" of a specialists' community. Nevertheless, a detailed analysis of the scientific production relative to knowledge management shows essentially that the management of knowledge and competence became a preoccupation in a big part of sciences and techniques. This is translated by a big number of actors (university, consultant, industrial, etc.) constituting a community of preoccupations, a profusion of publications, various networks and a rising offer of specialized trainings. But the big variety of points of view and interpretations which join to the knowledge and competence management calls up to a lot of caution as for any other scientific discipline, and invites to understand the senses which are given to them. Indeed, no fundamental scientific result appeared: literature supplies are only approaches which hold more feeling than it is important or are very pragmatic applications, sending back mostly to particular cases of companies.

Keywords: Knowledge Management, Knowledge, Multi-disciplinary Approaches, KM in Design

1 INTRODUCTION
This paper aims to present a consolidated set of results from a general study of the research work that has been done in the area of knowledge management and analyses its evolution throughout the last ten years. Knowledge management as a topic is known since a long time as a wide and raising one, dealing with several concepts in various domains. However detailed studies about the development over the time and the progress within the concrete domains, is missing.
For this study, we have considered a wide range of disciplines, to ensure that we get a large picture of the areas dealing with knowledge management, the related concepts used to develop the activity and the evolution of the explored subtopics. Our study is based on the following set of questions we developed. They are not necessarily all answered in this paper but we consider a maximum of them to come to a valuable result that allows us to present the current situation.
Can knowledge management be seen as a discipline? If yes, what are its principles, theories and models? Are they new? Are there any theoretical results on which the administrators and\or the researchers can base to build models, tools and solutions? Otherwise, to which fundamental science (s) does it belong or does it send back? And what theoretical results can we get from it?
Controversies are indeed numerous and opinions differ from one discipline to another. Based on this understanding, the paper has the only ambition to guide the reader towards an multi-dimensional understanding of this problem so that he/she will be able to build an opinion in this domain, shielded from certain assertions which show, at each stage of the industrial preoccupations evolution, that efforts often raise from the opportunism rather than from scientific areas.
Without claiming to give a consensual definition of knowledge management, one can sketch the evolution of the preoccupations that led to the emergence of this problem. Industrial development started at the beginning in terms of production resources. One was in the situation of a "world that adapted itself to the machine". Then followed a period, in which the logistic supply circuits and

products transportation in the company raised new problems. One distinguishes also the period during which the adaptation of the machine and the process to the product interested many researchers. Human conditions, problems of transport and distribution were then treated. The problems of ergonomics with the adaptation of the machine to the shape came later. Finally the last period introduces the concept of integration, notably in the field of design, with the consideration of all the constraints of the product life cycle. The constraints of survival of companies urges every administrator to ask the following question: How can I increase / create a competitive advantage? In the first degree, in spite of the complexity of the problem, an answer brought to these questions is generally simple: It is enough to take one of the resources and\or constraints which arise in the company to operate an improvement, a modification or redefinition, to be able to claim to create a new preoccupation and so a new control level of creation of a competitive advantage. The respect for the environment, the consideration of the customer needs and the consideration of the knowledge are examples for this generation process.

2 KNOWLEDGE, A KEY CONCEPT

In this wide panorama of conferences, networks and reviews, the term of "knowledge" is, naturally, explicitly or implicitly a pivot concept of various articles.
One will not enter, here, an ontological approach of the knowledge or in an investigation of the "knowledge of the knowledge". On the other hand, various studied articles give evidence of a variety and a polysemy associated to the notion that it is advisable to realize, as for themselves as for their implications compared to KM.

2.1 Discussion about definitions

Due to a lack of finding definitions, which make unanimity among all these actors in the field of knowledge management, what would lead us moreover to look for an approach and to open an ontological discussion of the "concept" of knowledge, one will notice that the various authors seize the term in a pragmatic perspective: the characterizations of the term "knowledge" make compared to the concrete ends of use and management of knowledge in company. One gives in the following some examples of such an approach:

1. Knowledge is information organized for the resolution of problems (Woolf, 1990).
2. Knowledge is information that was organized and analyzed to make it understandable and applicable for the resolution of problems or the decision taking (Turban, 1992).
3. Knowledge covers implicit and explicit limitations placed on entities, operations (Sowa, 1984).
4. Knowledge is the set of the truths and faiths, perspectives and concepts, judgments and anticipations, methodologies and know-how (Wiig, 1993).
5. Knowledge is the set of mental representations, experiences and procedures which are considered as true and right and which guide reflections, behavior and communications among persons (Der Spek and SpijkerveT, 1997).
6. Knowledge is reasoning about the information to guide actively the execution of a task, the resolution of problems and the decision taking for the learning and the education (Beckman, 1997).
7. Commercial knowledge is a network of imperatives developed explicitly and administered, of plans, rules written and contained in a part of the company and distributed within the company and which create performance on the market (Desmarest, 1997).

These various definitions send back to an approach of knowledge that places it in diverse levels while being logically organized: explicit knowledge (vs. tacit), abstract knowledge (vs. concrete), declarative knowledge (vs. procedural), etc.

2.2 Characterization of knowledge in the company

As a resource (to produce and to administer) for the company, knowledge distinguishes itself from "classic" resources of the company (material, energy, etc.) by the following points:

1. Knowledge is inviolable and difficult to measure;
2. Knowledge is volatile;
3. Knowledge is not consumed, it is in a way increased during its use;
4. Knowledge is mostly carried by agents;
5. Knowledge can not have "rival's" status in the sense that it can be used at various places at the

same time;
6. Knowledge has a very wide impact on organizations.

Besides, studied articles seem to send back to a hierarchical vision of knowledge, the elementary notion of "data" to that of the competence by way of notions ("more and more complex") of information, knowledge and knowing.
Beyond this, a strong investigation is put on the relation between knowledge and domains of value or meaning: the meaning of such knowledge is not envisaged in itself but constantly referred to a more or less spread context of evaluation which gets organized in functionally different "levels".
Finally, this notion of knowledge joins in a proper context (the company, the organization in action, etc.) that confers an echo otherwise an organizational dimension. Often authors use the idea of "organizational knowledge", which joins in the following alternative
1. Organizational knowledge is the collective sum of resources centered on the human being, of intellectual resources, resources of infrastructure and resources of the market (Brooking, 1996);
2. Organizational knowledge is the handled information, encapsulated, in routines and procedures that allow action. It is also knowledge captured by systems, processes, products, rules and culture of organizations (Myers, 1996).

Nevertheless, in both cases, one double tacit paradigm works:
- The intelligence of an organization is superior to the sum the individual secret relations of every individual constituting the organization;
- Individual intelligence in an organization is superior to the isolated individual intelligence

In this context, connecting knowledge and organizations within approaches stemming from the information, one underlines that two problems raising human sciences and sciences of management can be articulated in connection with an initiative or a KM politic: organizational learning and the "management" of knowledge in which this one is envisaged as an immaterial asset.

2.3 Several "schools of thought", definitions and approaches of KM

There are as many definitions as schools, as many definitions as disciplines concerned directly or indirectly by KM. This does not absolutely exclude the existence or the aim of a universal definition of KM! We have to go one step further as this constitutes one of the challenges in this rising discipline if it wants to be recognized as such. According to the "pragmatic" tradition, defended by Davenport and Prusak, KM is a stream, a mixture of experience, values, contextual information and experts' practices that establish architecture for the evaluation and the annexation of new experiences and information. Van Krough and his colleagues state that knowledge covers the faiths of group and the individual's faith and that it is connected closely to the action.
It is also interesting to revisit the two forms of knowledge: tacit or explicit. The first was defined and was introduced by Polanyi and popularized then by Nonaka and Takeushi. The second is the one that was codified by means of a formal or semi-formal language. This brings us to remind that according to Nonaka and Takeushi, the tacit shape towards the explicit shape and vice versa can convert knowledge. Social interaction between these two forms constitutes then the source of the creation of new knowledge and innovation.
From a disciplinary point of view, we can hold the caution of the group of researchers around Butler (1999) that recommends a sight of KM as a combination of mechanistic and humanist disciplines.
The followers of Knowledge Engineering define, KM as a collection of the processes which describe and administer the resources of knowledge type of an organization and which govern conservation and extension of these means.
Liebowitz (2001) defines knowledge management as a set of the processes of consecutive creation from the inviolable resources of an organization.
As for Stefan Decker and Franck Maurer (1999), they consider that knowledge management can be identified through its basic activities that are: identification, purchase, development, scattering, use and conservation. Or, as suggested by Abecker and Decker (1999), the management of knowledge bases on a pit constituted by the information system support of the organizational memory representing a coherent integration of different know-how scattered in the company. It also has to have architecture allowing a construction and an easy maintenance; an orientation towards maintenance by an expert would assure failure in more or less short term. Finally, such an organizational memory has

to have tools of use and search. In any case, it is advisable to deviate from any non-specialized or very specific solution for the benefit of solutions rather than person-adapted, evolutionary and adaptable. From another point of view, defended by Gertjan Van Heustand (1997) and his Dutch colleagues of the kenniscentrum cibit, organizational memories also have to allow learning at three levels, namely individual learning, learning through direct communications and learning by the use of knowledge based system.

2.4 Several locations of the management of knowledge

In the widest sense, knowledge management constitutes of the capacity to develop intellectual capital to reach the objectives of an organization. This majority allows containing the very varied approaches which one can observe. One can say that there are two schools of thought: the first is the "rationalism" which sees knowledge as something being able to be obtained deductively from mental processes, second is " the empiricism " which sees knowledge as something to be obtained by induction (that is by experiment). So, the notion that integrates these two traditions into the definition of knowledge joins in the philosophy of the pragmatism in which thought (rationalism) and action (empiricism) are in interactive relation.

One perceives the tension which can appear between rational knowledge and empirical knowledge, more or less well rationalized. This raises the question how to store, to index, to deal, in brief, "to administer" this knowledge?

Besides, in a world of competition based on the exploitation of knowledge, its development and its use, any activity faces a challenge: that of the balance to be found between the creativity and the flexibility. A priori, less bureaucracy increases and favors spontaneity, experiment and freedom of expression that constitutes the vital blood of innovation. On the other hand, the management of knowledge (in the sense) of knowledge engineering, due to the important number of necessary alterations to the process from the idea to the development of a product or a service can constitute an obstacle and oppose the conditions of genesis of the innovation. KM should always find a balance between these two degrees of freedom (Amrit & Balasubramaniam 2001).

Finally, to share knowledge, technology is not sufficient for KM. Developers begin to understand that individuals and the culture of the workroom are factors leading to the success or to the failure of KM initiatives. Concentrating only on technologies, limits the perspective that one could take. In this frame, authors such as Liebowitz and Beckman (2001) remind us that KM must be integrated within the strategic objectives of organizations if one wants that it allows the improvement of performances.

3 POINTS OF VIEW, CONTEXTS AND STRATEGIES

We have just operated an approach of first level that consisted in building a characterization of the preoccupations of the manufacturers and the researchers during the last decade. A more detailed observation also shows an interweaving of tools, theories, and approaches of KM with different reference disciplines.

We put back on figure (1) the cartography of reviews receiving the rates of the researchers in the field of KM. One can there notice the referring of tools, theories and the other approaches with different problems raising, notably, decision sciences, information sciences, social sciences, cognitive sciences…

The processes of knowledge are so seen under several angles that send back to established problems and guide the point of view on knowledge management. There is actually one (or some) relation (s) - somewhere else more or less explicit - between the pragmatic point of view, which join considered articles and bases of more ontological nature from which these points of view take.

For example, when knowledge is envisaged as " information organized for the resolution of a problem, the idea of knowledge sends back implicitly to entities already formalized compared to such processes of resolution (statements susceptible to formal treatments) or, a minima, in organized categories without, formal processes of treatment are a priori associated. But, as the author will proceed from a point of view bound to the information sciences or, for example, the linguistic point of view, the meaning and the practical echo of the comment will not be the same nature.

In other words, the notion of knowledge must be at the same moment considered by a pragmatic point of view (what it conveys of meaning in a certain context of action) and in reference with an ontological context (or universe) which directs and limits, actually, this field of meaning. Consequently, the epistemological level would be important to be considered.

Beyond the implications that such a work would suppose, two other contextualization of the pragmatic approach of the knowledge notion should also be considered:

1. The contextualisation connected to the company itself: the peculiar character of any KM system, referred to the particular context of such company. Even though one can envisage generic approaches, every company supposes otherwise peculiar particular approaches.
2. The contextualisation connected to the strategic perspectives in which a KM system is envisaged and is implanted. Indeed, as one aims at a strategy of innovation or at a strategy of help for the decision, approach will be inevitably different.

For example, in the articles studied in this paper, one distinguishes at once five different sides for the implementation strategy of a KM system and, therefore different methodologies:

- Strategy of business;
- Strategy of intellectual resources management;
- Strategy of the personal knowledge responsibility;
- Strategy of knowledge creation;
- Strategy of knowledge transfer.

4 DOMAINS AND SCIENCES ADDRESSING KM

The first step in this study was devoted to the identification of the scientific fields dealing with knowledge management from the content point of view. Figure 1, reports the comparative results. In term of inputs in the area, we can state that computer science, operational research and management are those areas with the largest history and thus have influenced the developments of the field.

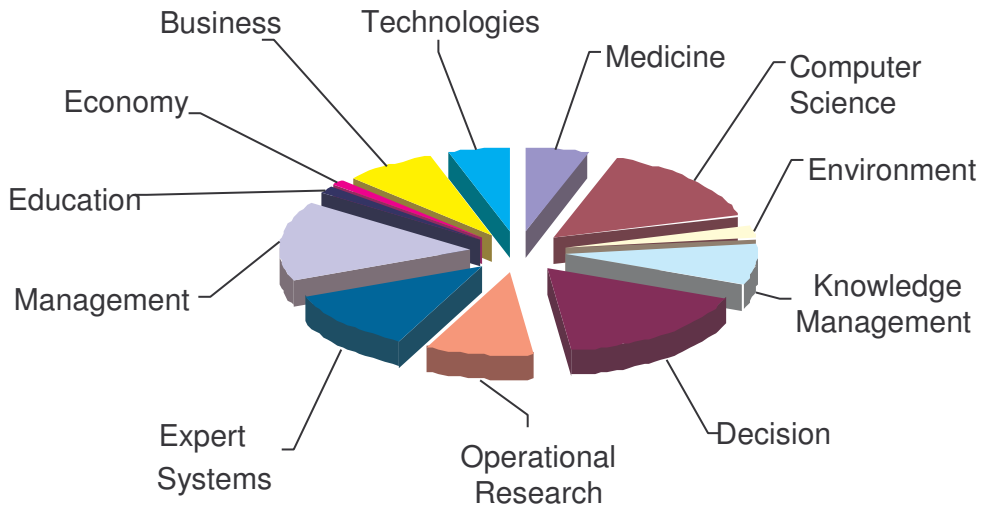

Figure 1: Domains through the exam of networks receiving published articles

5 EVOLUTION OF THE ACTIVITY

The following study considers the knowledge management research results provided in international journals. The material used is thus liable thanks to the deep review process required by the editors. In fact, lot of works have been done and not considered in this paper, such as publications in books, magazines and conferences.

Based on this, we have considered the evolution of the publications is several areas. Among the whole domains and sciences we have chosen:

1. Decision science (DS)
2. Social sciences (SS)
3. Engineering (EG)
4. Computer science (CS)
5. Medicine and Health (MH)
6. Business and economy (BE)

We consider publications during the last decade i.e. since 1995. The year 2006 is added here in order to get an idea on the possible evolution during year knowing that this analysis considered the publications until end of April 2006.

It is interesting to notice that during the first years (1995/1996) no major publication has been identified. One can see (Figure 2 : Evolution in Decision Science) that since this period we observe a continuous linear progression of the contributions. 1995 seems to be the "apogee" of this period. We can probably state that knowledge management is now mature and the related tools and techniques are integrated within the decision processes

If we consider the evolution in details, we can notice that after a rich period follows two years with fewer contributions. This might mean that regular research activities are conducted after each period of publication leading to significant results.

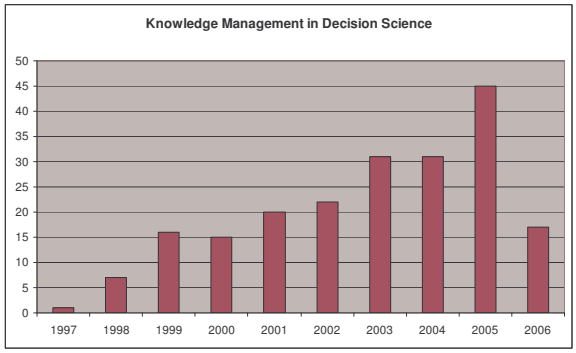

Figure 2 : Evolution in Decision Science

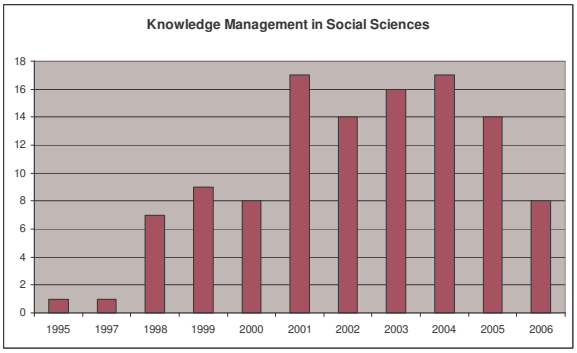

Figure 3 : Evolution in Social Sciences

5.1 In Social Sciences

Social sciences addressed the knowledge management related issues since the beginning (1995). While the number of contributions is generally less than for decision science, we can see (Figure 3 : Evolution in Social *Sciences*) that this domain is leaving activities in knowledge management. It is difficult to extrapolate this evolution; however we can probably expect a continuation of this behaviour.

5.2 In Business and Management

Business and Management is the area where one can see that knowledge management is a real research field receiving, comparatively to the other domains, the most important quantity of contributions (Figure 4). We can also notice that the continuous evolution shows the potential one can have to collaborate with researchers in business or management when coming from another field.

5.3 In Engineering Applications

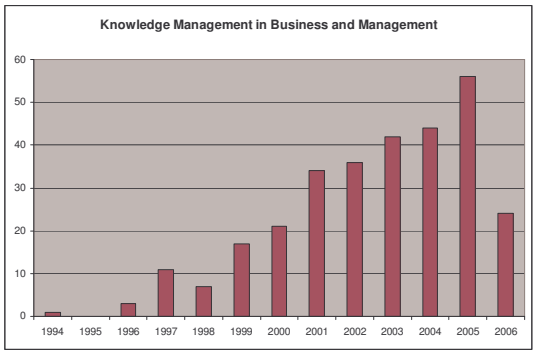

Figure 4 : Evolution in Business and Management

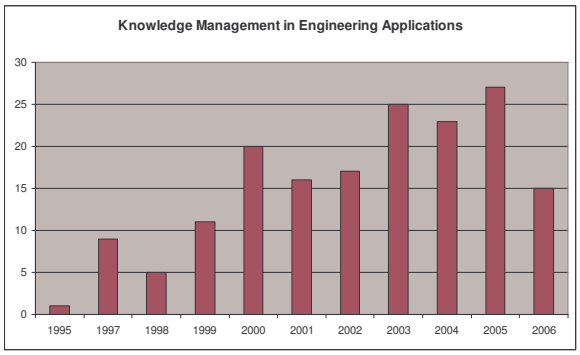

Figure 5 : Evolution in Engineering

The engineering applications and studies addressed the knowledge management field since the beginning what shows that it is now mature. Contributions from this field, even if on a regular progression, are still modest.

5.4 In Computer Science

Computer science as a fundamental discipline has a parallel evolution compared to business and management. However, the understanding of the "knowledge Management" concept differs. One can see that even if there is not an immediate link between these two disciplines, their contributions are continuously growing.

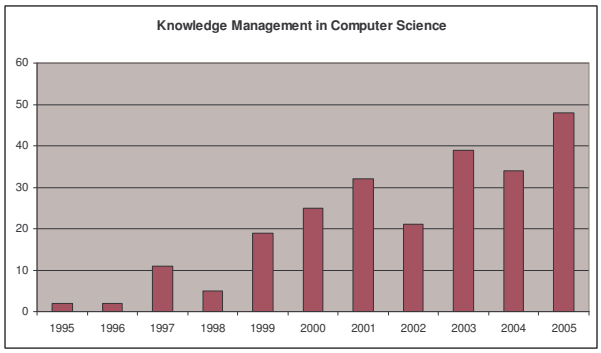

Figure 6 : Evolution in Computer Science

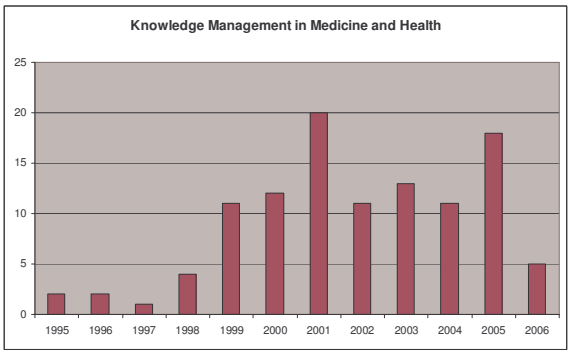

Figure 7 : Evolution in Medicine and Health

5.5 In Medicine and Health

For medicine and all related sciences, the contributions seem to be hesitating. They follow more a less the evolution in social domains. Surprisingly, while expecting the same evolution as in engineering, the results point out that KM is less addressed explicitly as such.

6 SHARED CONCEPTS

The quantitative study provided in the previous sections gave place to the justification of the areas we have considered and the analysis of the potential future of knowledge management from different perspectives.

The question that rises directly from this is related to the concepts used by these disciplines. Can we identify the different schools of thoughts? Is there any common background between all these disciplines and sciences when dealing with knowledge management? Are there subsets of disciplines sharing strong concepts? Is the terminology used in knowledge management consistent?

We have analyzed the 658 papers dealing directly with knowledge management and extracted the concepts used. In total we get 1317 different keywords, ideas, methods, tools etc.

The primary analysis shows that there is no common concept between all the disciplines (we did not consider those obvious such as knowledge, knowledge management…) see Figure 8. This figure shows also that the domains we have considered are justified by the fact that they own specific concepts not shared with any of the other disciplines. Among them engineering science owns a whole ontology of concepts that allows saying that they belong to a specific school of thoughts. The second position is taken by the business and management field. One can see that even with a larger number of contributions, this domain is not generating new concepts compared to engineering applications.

At a second level, we can consider the couples of disciplines and see that medicine and business/management do not share any specific concept that is not used in another domain. As an outcome, we can state that there is a field to be opened here. In contrary, between engineering and social science 34 specific concepts are shared. We can state that the cooperation between these two disciplines is now mature and from both sides the benefit in collaboration is appreciated.

The case of medicine and social sciences is more obvious, since the collaboration between them exist since a long.

Knowing that in many cases, knowledge management studies lead to software solutions, we were expecting a large number of concepts shared between all the disciplines except computer science. The results we get from the study shows actually the contrary. This means that, even if we need in many cases software solutions, it doesn't mean that there is a common background between all the disciplines which in turn means that computer science plays the role of communication media.

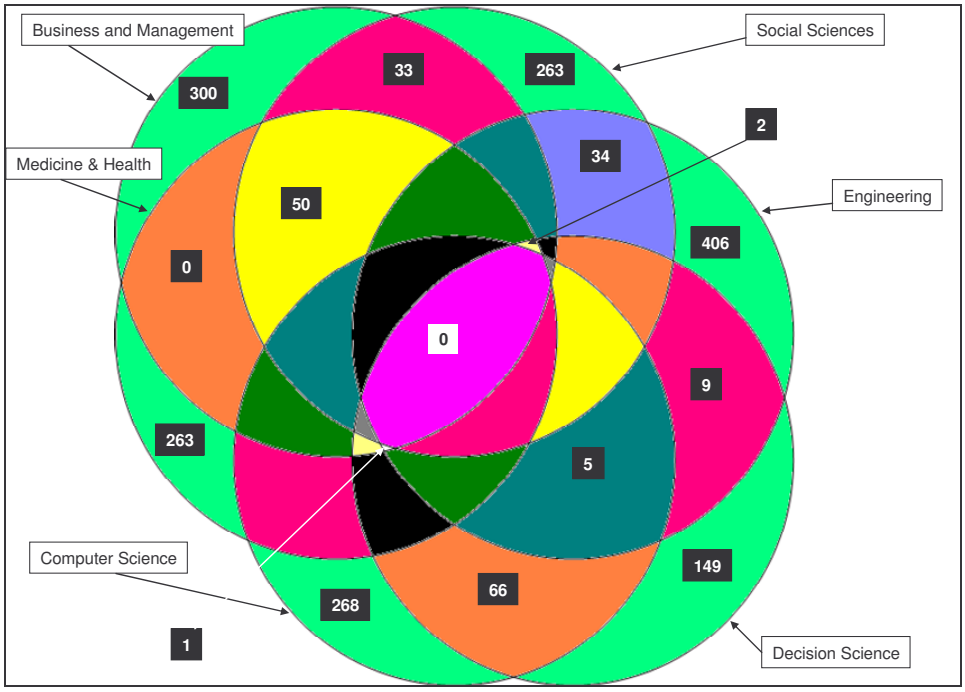

Figure 8 : Shared concepts in Knowledge Management. A quantitative analysis

7 MAPPING INTO ENGINEERING DESIGN

A deeper study of the concepts shared between those disciplines addressing the same research areas, shows (figure 9) a common understanding of some issues. In fact, four main chapels can be pointed. The representation of the decision processes in design and the integration of knowledge management tools and methodologies as support, constitute one of the main areas. This includes mainly:

- Modeling knowledge along its lifecycle (see figure 10)
- Development of infrastructures to handle the KLM (Knowledge Life Management)
- Development of knowledge-based decision systems
- Development of man/machine interfaces to make the KLM realistic and efficient

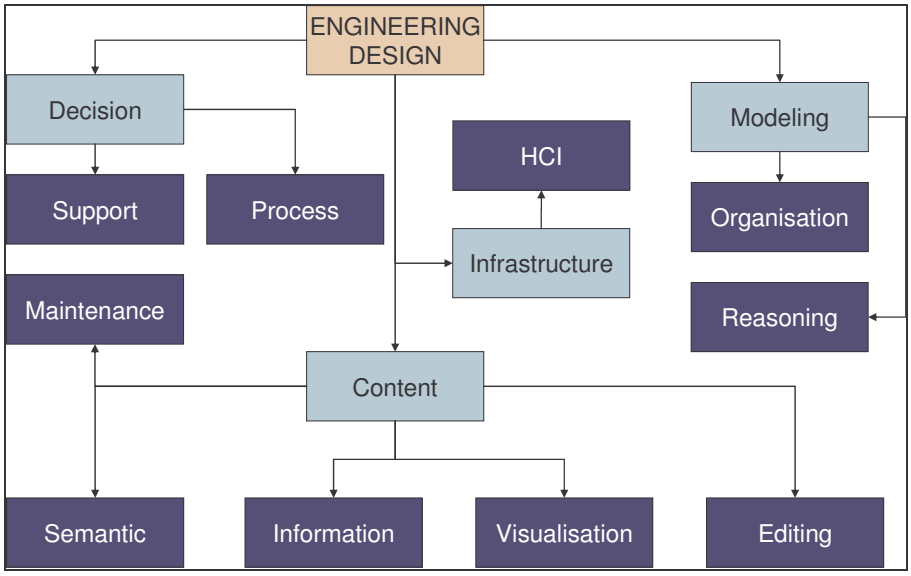

Figure 9 « Concepts used and shared in Engineering Design »

From a multi-disciplinary approach, the lack of convergence is mainly due to the four different directions covered by the approaches:

1. Reasoning
2. Business
3. Engineering
4. Sociological & Psychological issues

This lack of convergence needs further works to provide an integrated framework that goes beyond the proposed one in engineering fields as shown in figure 10.

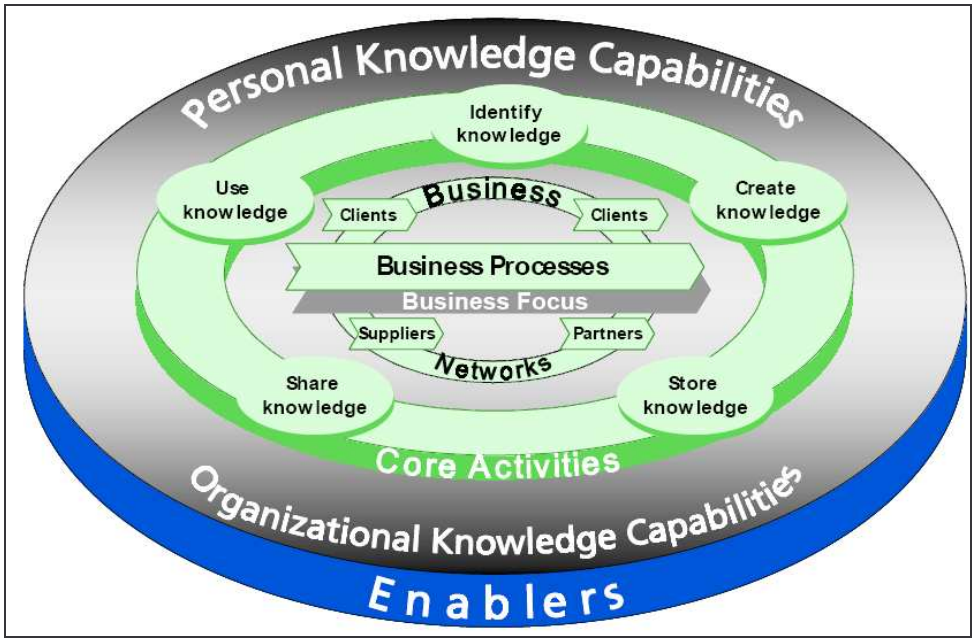

Figure 10 "Knowledge Management Framework as Established by the European Standard"

According to our study, future work needs to be based on the following key aspects supported by results from a study on the use of KM technologies and approaches in industry (figure 11):

- Mission, Vision & Strategy;
- Culture;
- Process & Organization;
- Measurement;
- Technology & Infrastructure;
- Knowledge Assets.

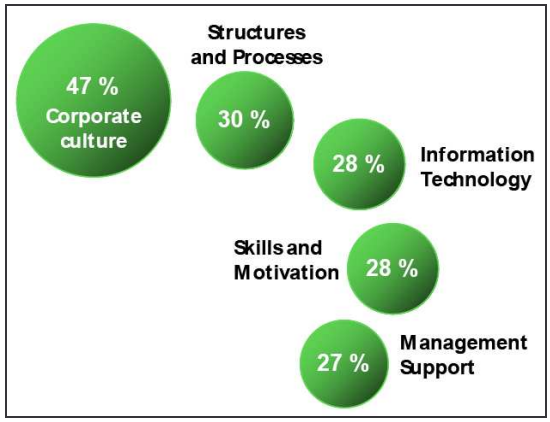

Figure 11 « Results from a survey on successful KM use »

This framework should serve as a point of reference in engineering to help raising awareness about how knowledge is used, where to start with KM initiatives and which are the most relevant aspects and enablers to be considered when embarking on a KM project.

Nevertheless, every organization has its own identity, language and culture. Therefore, the KM multi-disciplinary framework presented (figure 10) should not be taken as a single solution for organizations, or the best way to do KM, but merely as a well-founded basis for discussion to help them with further definition of their own specific KM framework.
While developing and implementing a KM solution, an organization will usually embark on a change management process, by attempting to change some the beliefs and behaviours of the management and the employees. The dimensions of this Framework could therefore help an organizations' KM project team to check whether all relevant factors are addressed within the implementation and change processes. Despite the long-term perspective of most change programmes, short-term improvements and so-called "quick wins" have to be achieved in order to maintain momentum and commitment on all organizational levels.

8 CONCLUSIONS

This paper is a new step in the process started in 2001 in order to get a comprehensive knowledge about the reality of knowledge management. We have shown that starting from a believe that we have only two schools of thoughts, the reality shows that now we are facing 6 different domains with specific concepts. On one hand this demonstrates the richness of this area, but it also shows, on the second hand, that we are following a divergent flow. Consequently, and from the epistemological point of view, knowledge management cannot be considered yet as a science.
The second outcome of this study is related to the new potential cooperation that should be considered, such as between medicine and business/management. Unfortunately, the frame of this paper doesn't allow the scientific analysis of the concepts shared and those specific to diverse areas. This will be likely provided in future contributions. The authors welcome any request to deliver this information.

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