

A MODERN FRAMEWORK FOR KNOWLEDGE PRESERVATION AT GOVERNMENT R&D ORGANIZATIONS

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ABSTRACT

Knowledge management – KM has attracted considerable attention in recent years and is being practiced in most of the organizations. In the nuclear area, the adoption of the expression “Nuclear Knowledge Management” emphasizes that there are a few knowledge issues and characteristics that are peculiar of nuclear organizations.

It is a fact that such organizations in most of the countries are facing an aging process of their professionals, as a result of loss of emphasis or phasing down of their nuclear programs and consequent low interest of young people to enroll in nuclear science and technology carriers.

For the reasons mentioned above, many of the KM initiatives in nuclear organizations have targeted the called class of “knowledge preservation problems”.

This paper describes a work that is being carried out at the Radioprotection and Dosimetry Institute, more precisely at the Ionizing Radiation Metrology National Laboratory.

The work addresses a number of problems that can be described in terms of the questions and approaches that are being used to solve it. A methodology encompassing process mapping and analysis, knowledge elicitation and mapping, critical analysis and sociotechnical analysis based on social network analysis have been put together. This paper describes the conceived methodological framework and gives examples of its application so far.

1. INTRODUCTION

The increasing competition in business environment, characterized by profound and rapid technological and social changes, turned knowledge into a valuable resource, an asset that is embedded in intellectual products (especially high-tech ones) and in the tacit knowledge of workers who are well appraised by the market. So, knowledge is increasingly being recognized as the primary source of value and wealth, which differs organizations and nations.

Knowledge, however, has some paradoxical features that differ it from other important resources: (Dalkir, 2005)

- Knowledge is not consumed in use;
- Knowledge transfer does not result in loss;
- Knowledge is plentiful, but the ability to use it is scarce;

- Much of the valuable knowledge of an organization goes out the door at the end of the day.

Actually, in the last two decades, knowledge management - KM is being practiced in most of the organizations. In the nuclear area, the International Atomic Energy Agency (IAEA), in the first part of the last decade, has undertaken a handful of initiatives promoting guidance and fostering the engagement of Member States in “Nuclear Knowledge Management” - NKM. By adopting this title, instead of just knowledge management, the Agency tries to make a point that there are a few knowledge issues and characteristics that are peculiar of nuclear organizations.

It is not that the nuclear area requires different approaches for KM but the knowledge problems of nuclear organizations have a profile that share similarities among their peers and that does not resemble with the profile that we commonly see in most of the knowledge intensive business organizations.

It is a fact that nuclear organizations in most of the countries are facing an aging process of their professionals and a substantial retirement rate. Among the retirees, inevitably there are experts who hold significant part of the strategic knowledge of organizations. This situation is a result of loss of emphasis or phasing down of nuclear programs and consequent low interest of young people to enroll in nuclear science and technology carriers, causing an adverse impact on preserving and further developing the nuclear knowledge and expertise that were accumulated over the last six decades.

This long enduring situation will probably tend to aggravate in the next years, especially after the Fukushima accident. Many of the nuclear organizations have experimented downsizing or a redefinition of their scope towards business or research fields outside of the nuclear area. Anyway, the mismatched rates of retirement and of new hiring has been unbalanced since long ago and should a revival of interest in nuclear energy come to strength in the next years, organizations will be faced with knowledge shortage problems of many kinds.

In Brazil, this situation also occurs in virtually all R & D organizations of the nuclear area. Much of the nuclear knowledge was developed in institutes that belong to the National Nuclear Energy Commission (CNEN), under the Science & Technology Ministry. One of CNEN's institutes, the Radioprotection and Dosimetry Institute (IRD), is an educational and R&D organization, acting in the areas of radiation protection, dosimetry and metrology. Through its National Laboratory for Metrology of Ionizing Radiation (LNMRI), IRD is responsible for the activities of scientific and industrial metrology in the field of ionizing radiation, as the Designated Institution by the National Institute of Metrology, Quality and Technology-INMETRO. IRD has 260 permanent employees in its technical-scientific workforce, of whom about 23% PhDs and 20% masters. Due to a policy of low replacement of the retired workforce, IRD has had a gradual reduction of its personal. The current average age of employees is about 50 years. It is estimated that by 2015, about 50% of the employees will be retired, hampering the execution of many institutional activities. Thus, it is a great challenge to transfer the essential knowledge of the retiring experts to the remaining workforce.

Although knowledge management is not formally considered at IRD, some organization's practices can be highlighted as specific KM initiatives. Therefore, somehow, although not

systematic, "knowledge is managed." However, it is not possible to assess the efficiency and effectiveness of such practices since it is not possible to quantify their results and long-term effects.

According to Terra, (2005), KM is a set of actions to organize major policies, processes and managerial tools and technology for a better understanding of the processes of generation, identification, validation, dissemination, sharing and use of strategic knowledge to generate results (economic) for the company and benefits for employees.

Some typical goals of knowledge management are:

- Enabling the smooth transition of those who retire to his successors who are recruited to fill their positions;
- Reducing of loss of collective memory, due to evasion and retirement;
- Identifying of critical resources and areas of knowledge to the organization;
- Building a set of tools and methods that can be used to restrain the potential loss of intellectual capital of the organization.

There are several KM methods and tools (Dalkir, 2005; IAEA, 2012). However, the choice of the right tools and techniques should be consistent with the organization's business strategy, objectives and goals (Dalkir, 2005).

Once recognized the problem and the motivation to solve it, an appropriate framework was designed for such purpose, in view of the characteristics described above. This framework and its corresponding application to LNMRI at IRD are the subject of this article, which reports the current status of this research.

2. METODOLOGICAL FRAMEWORK

Obviously, like any other form of management, an effective approach of KM should be selective and treat differently the different objects. So, to better qualify our management objects in a practical way, such characterization can be done analytically by answering the following questions:

1. What are the processes of the organization that if discontinued would have the largest impact (direct or indirectly) on:
 - a. the mission itself and
 - b. end users (occupational workers and general public)?
2. What are the relevant, non-common knowledge that enables those processes, to be performed within the adequate quality levels?
3. Who possesses this essential knowledge?
4. How is this knowledge base mapped into the organizational memory, considering both:
 - a. explicit knowledge objects and
 - b. implicit ones (those residing in peoples' mind)?
5. From what was identified by answering question 2, what are the critical knowledge objects considering:
 - a. Relevance;
 - b. availability in the organizational memory;
 - c. learning curves,
 - d. vulnerability and cost of replacement

6. How to identify the mechanisms of knowledge transfer that are used by coworkers in daily activities, even if they are not part of the formal working processes?
 7. What can be done to assure sustainability of the critical knowledge in the organization?
- In order to get answers for these questions, it is important considering the IRD as public institution, which a mission concerned with public values and wellbeing.

To set the research's scope, it was defined as object of study the LNMRI, taking into account the strategic importance of metrology of ionizing radiation, to ensure the quality and reliability of the measurements in the context applications of nuclear technology.

The table below shows a summary of the methodological framework used, whose items will later be described in the following sections.

Table 1: Methodological framework

Issue	Criteria	Methods and Tools	Results / outputs
process relevance	mission impact	documents and data analysis	selected processes
	end user impact (number, quality of loss)	interview with management chain	
enabling knowledge	requirements (background knowledge)	engagement in process learning	knowledge objects identification (including skills needed)
	process knowledge	process mapping	similarity of knowledge objects
	specific ability	on site observation expert interviews	
knowers	who knows what	interviews	knowers mapping
	proficiency level	management assessment	
organizational memory (OM)	artifacts and knowers mapping	documents, data bases and systems analysis	reliability of organizational memory
critical knowledge	relevance	questionnaire applied to experts, pertinent data bases analysis	knowledge objects classification
	availability in the OM		ranking and assessment of learning curves.
	learning curves vulnerability and cost of replacement	expert interviews	assessment of potential loss of knowers
informal transfer mechanisms	existence and effectiveness	questionnaire applied to the staff	assessment of the culture for sharing knowledge
		expert interviews	informal mechanisms that should be leveraged
		on site observations	
in depth analysis	sustainability level	mapping of knowledge related social networks	knowledge related key personnel
		sociotechnical analysis using meta networks	assessment of organization vulnerability
			ranking of critical knowledge according to different perspectives

3. METHODS AND TOOLS

The description that follows comment in some detail, what methods and techniques were used to answer each one of the above mentioned questions and also what results were (or are expected to be) obtained. In each case, a distinction will be made to show what has been already accomplished and what is still being carried on.

3.1. Identifying relevant processes

Although administrative processes, especially those related to customers and suppliers are important, it was decided to address only technical processes. This is mainly because they are based on the unique and distinctive competencies, which enable the LNMRI to perform its activities as expected. From this point, two classes of criteria were adopted to the selection of LNMRI's relevant processes, as follow:

a. Connection with IRD's mission and vision;

It was used a five point interval scale, where 5 = strongly and directly relevant to the mission accomplishment and 1 = weakly and indirectly. A similar question was applied to the vision.

b. Impact if the process has to be discontinued:

It was adopted a five point interval scale, considering two aspects:

- gravity; where 5 = very high and very low = 1
- breadth or scope; where 5 = many direct and indirect end users and 1 = very few end users.

The survey was carried out involving experts and managers who are familiar with the process and have a clear view of customers' needs and of the mission and vision of the IRD.

To gather information for such evaluation, data from the last three years of services provided by IRD that are related to the concerned processes were collected. The clients to whom those services were provided were classified by segment according to their nature, in such a way that we can assign a relative importance to service, in terms of impact, should it be discontinued.

3.2. Identifying enabling knowledge

For the purpose of this research, it is considered "enabling knowledge" the set of knowledge that make possible the execution of the corresponding processes, with the required quality level. In the identification process, the following sources of knowledge were considered: technicians, experts (implicit sources) and procedures, databases, documents with reports of experiments (explicit sources). It must be mentioned that the personal insights due to the experience of the researcher (interviewer) has played some role in process.

To address this issue, a three-step approach was always followed: (a) process mapping; (b) field observation and (c) interview with experts. In some cases, when necessary, the researcher decided to get involved in learn how to do process in order better distinguish the enabling knowledge.

IRD runs a quality management system (QMS) in accordance with the requirements of NBR ISO/IEC-17025 standard. Therefore, most of the processes considered in this study, is

described in QMS's documents. They are kept updated and managed in the form of electronic media in a database at IRD's intranet. Similarly, records of the routine measurement, job profile and qualifications required are also kept in a data basis. These were the first information source to understand the processes to be mapped.

The next step was a combination of observation of processes execution and unstructured interviews with the responsible persons. The objective was to get a deeper understanding of the processes and identify the actual knowledge that is needed to carry them on.

Considering the previous knowledge of the researcher and the specific knowledge acquired mapping all the relevant processes, it was possible to devise a representation model for each process and also a unified questions roadmap to interview the experts. This was possible given the similarities that were identified among the processes.

Using the question roadmap, semi-structures interviews were conducted with each expert to address knowledge related to the processes and any specific peculiarities of the execution steps. Interviews could take many sessions according to the complexity of process at hand.

After the proper note taking and representation of the process, the mapping and enabling knowledge identification were validated with the proper experts and responsible persons. In this step a technique called teach-back was adopted, in which the interviewer, attempts to teach the information back to the expert, to who then provides corrections and fills the gaps (BURGE, 2013).

Business Process Modeling (BPM) notation was used to represent the processes as a way to provide a clear vision of their flows and the interaction between their steps and related activities, as well as the involved agents.

Information on the background knowledge required to each process, which was collected from the records of the job profile and qualification required, available in the IRD-QMS data base, was also validated and eventually updated during the interviews.

3.3. Identifying knowers

Considering the similarities already identified among processes, it was not surprising to observe that some enabling knowledge are present in various processes. By the same reasons there are knowers of the same knowledge domain working in different processes. Therefore enabling knowledge was grouped in areas of identical or nearly identical domain, which we designated as knowledge objects. Using these knowledge objects, individuals were mapped as holders or knowers of those objects according to their degree of proficiency.

To do so, a table with the knowledge objects denomination and the names of all personnel will be used in conjunction with a four point interval scale for the proficiency level (4= highest degree and 1 lowest degree of knowledge). Of course no association was made for knowledge not possessed by a person. Table will be filled by the individuals and validated by responsible managers.

At present this map is being carried on and upon conclusion it will contribute to a better characterization and better reliability of the organizational memory.

3.4. Assessing organization memory

Organizational memory (OM) can be directly related to the capacity of the organizations to store, retrieve and make wise use of information and developed knowledge for their needs, actions and decisions. Such memory is primarily distributed in the individuals' minds, organizational culture, documents, data bases and systems.

The objective here was not to pursue a complete evaluation of the IRD organizational memory, but just to assess the reliability and completeness of those items related to the previously identified knowledge objects.

An example of an item that will be of great utility when aggregated to the OM is the knowledge objects – knower association table (who knows what) described in the previous section. Such information is of great value from a management point of view and presently it is not available in a systematized form.

3.5. Identifying critical knowledge

Our approach was based on the literature that discusses this issue in the context of strategy and resource based view of the organization. More specifically we have used the texts of Grant, 1991, Collins & Montgomery, 1995, Amit & Schoemaker, 1993, Ricciardi; Barroso & Ermine, 2006, which consider critical knowledge as a crucial factor for the organization's performance. To do the classification, we have devised a simplified approach considering criteria related to organizational performance, preservation of knowledge and risks associated to their respective loss. Table 2 shows the definition of the criteria we are using for the evaluation and prioritization of the enabling knowledge previously identified.

Table 2: Criteria for evaluating knowledge's criticality

Criteria	Description
Relevance	Refers to the degree of importance such knowledge object plays in one or more processes for which it is an enabling item.
Availability in the organizational memory	Refers both to the number of holders in the organization and how well documented and retrievable it is in the organizational memory.
Learning curves	Refers to the time and effort necessary for a newcomer, with the required background knowledge, to acquire the necessary proficiency level. Both the complexity of the content as well as specific skills is considered.
Vulnerability and cost of replacement	Considers the risk of losing the knowledge because of the outflow of personnel and the cost of replacement considering its availability inside or outside the organization.

This assessment is being conducted at the moment and a three point interval scale is being used.

3.6. Identifying informal transfer mechanisms

This issue was addressed through informal conversations with some LNMRI's staff members and the division heads, but a longer period of observation is necessary so that it can be said that such mechanisms were mapped. So far we have identified the conversations among peers and possibly discussions with the speakers, when people get together for internal seminars, which occur every 15 days. Regarding the exchange of knowledge relevant to the processes involved in these interactions, we still have to create a tool to analyze the occurrence and effectiveness of such a mechanism.

Note that this seminar was created recently (since April 2013), with the initial goal of providing a space for integration of researchers and to promote some kind of spontaneous discussion on topics of LMNRI's interest.

3.7. In depth analysis

Given what is described in sections 3.1 to 3.3, it is possible to construct a meta-network, comprising various bimodal networks, with the following entities: processes, process-steps, knowledge objects and persons. The first network involves processes and process-steps; it is similar to precedence diagram and just displays the connections of the process flow. The second involves persons and process-steps describing who is in charge of each step. The third show the connections between process-steps and knowledge required to carry them on. The fourth plays with people and knowledge objects and has weighted links that indicate the level of proficiency each person possesses with respect to a given knowledge.

In addition a reputation network will also be mapped using the questions:

- To whom do you talk when you want to discuss technical issues related to your work?
- How often does this happen?

With all these networks mapped, an in depth socio-technical analysis can be done, using social network analysis methods and tools, to assess the knowledge issues of LMNRI.

4. RESULTS AND DISCUSSION

Among the selected processes according to 2.1, two of them are presented below as examples:

- a. Calibration of radioactive sources by the primary method of coincidence $4\pi\beta\gamma$ - Quantity: activity per mass unit (Bq/g);
- b. Calibration of ionization chambers in the X-ray beam of low and medium energy - Quantity: absorbed dose air; air kerma (Gy = J/Kg).

From the point of view of both the mission and the vision of the IRD, the two processes are extremely relevant, since they enable the accomplishment exclusive assignments of a national metrology institute (NMI) i.e. to maintain and preserve the national measurement standards, as well as deploy and maintain the chain of traceability of standards of measurement units in the country. If one of these processes were discontinued, there would be a break in the Brazilian metrological structure, which means breaking the link between the measurements made by the laboratory service providers in the country, with the National System of Units (SI). As a result of that, products and services such as certified radioactive sources and standard, programs of quality assurance in laboratories and applications of

radiopharmaceuticals in nuclear medicine and calibration of instruments in diagnostic radiology, must necessarily be supplied by the external market.

Regarding to the gravity and the breadth or scope of the processes, the LNMRI is the only organization in Brazil, which provides certified radioactive sources to users. About 90% of all radioactive sources produced in the last three years, are traced to the SI through the primary process of coincidence $4\pi\beta\gamma$. Are direct users of the system, LNMRI own labs to calibrate their measuring systems. The indirect users are the laboratories of CNEN, running measurements activities, nuclear medicine services, universities, oil companies and other branches of industry. Therefore, the consequences of disruption of this process would be severe especially for medical applications which have a direct impact on population health.

Similarly, the calibration of ionization chambers in X ray beam of low and medium energy promotes traceability for all laboratories in the country that perform calibrations in diagnostic practices (conventional mammography, computed tomography, bone densitometry , etc.), therapy (orthotic) and radiological protection. The latter, directly related to the safe use of ionizing radiation. Internal activities of the IRD would also be affected as in the case of research projects in medical physics, among others.

Some results obtained after the processes mapping and the identification of enabling knowledge are presented below, for the calibration of ionization chambers in X ray beam of low and medium energies. In this case, we identified two distinct processes, featuring two levels of proficiency: Deployment and operation of the system.

The processes were represented by steps and the corresponding critical knowledge, were identified, as described in sections 3.3 and 3.5. Table 3 shows some examples of results already obtained for the deployment process.

Table 3: Examples of methodology's application

Deployment of an X ray low and medium energies calibration process	
Step	Critical knowledge
X-ray source specification	Knowledge of how to assess and implement recommendations based in protocols, standards and guides applied in Radiodiagnosis; Knowledge of the parameters which characterize an X-ray generator and its influence in the beam (inherent filtration; electrical, mechanical and thermo-hydraulic compatibility).
Set up specification	Knowledge of the components of the set-up and the function of each one in the system (optical bench; X-ray tube fixing system); Knowledge of the influence of the absorbers' properties (density, purity, thickness) in the process of the interaction of the radiation with them, in order to characterize the required qualities.
Reference standard specification	Knowledge of the construction details and other characteristics of the different types of ionization chambers (energy dependence, operating voltage, nominal response, saturation limit, leakage current etc.), and their suitability for the measurement process, considering their contribution to the expanded uncertainty.

5. CONCLUSIONS

It is evident that NKM is vital for the continuing success of nuclear technology applications. In addition, since measurements are present in said applications, if the IRD's knowledge in ionizing radiation metrology accumulated to date is lost, nuclear safety and security in Brazil, may be at risk.

From the point of view of providing a systematic approach to answer the proposed questions in this work, the conceived methodological framework has been enabling good results, especially due to the complementarities between utilized tools.

Both document's analysis and interviews were an important starting point to understand and capture knowledge associated to an expert's knowledge domain. The association of observation of processes execution and the researchers' engagement in process learning has gotten a better understanding and identifying the actual knowledge that is needed to carry each studied process.

It's possible to say that upon finishing the data collecting phase, the authors will be able to perform a socio-technical analysis using dynamic network analysis methods and tools, to identify and characterize LNMRI's meta-network structure and thereafter develop strategies to reduce vulnerabilities and/or improve its performance. It will contribute for maintaining and developing of the nuclear knowledge acquired in the country over the last sixty years.

REFERENCES

1. AMIT, R.; SCHOEMAKER, P.J. Strategic Assets an Organizational Rent. *Strategic Management Journal*, n.14, p. 33-46, 1993.
2. BURGE, J. E. *Knowledge Elicitation Tool Classification*. Worcester Polytechnic Institute. Disponível em:<<http://web.cs.wpi.edu/~jburge/thesis/kematrix.html>>. Acesso em 19/07/2013.
3. COLLINS, D J. & MONTGOMERY, C. A. Competing on Resources: Strategy on 1990's. *Harvard Business Review*, n. 73, p. 118-128, 1995.
4. DALKIR, K. *Knowledge Management in Theory and Practice*. Burlington: Elsevier Butterworth–Heinemann, 2005.
5. GRANT, R.M. The resourced based theory and competitive advantage: Implications for Strategy Simulation. *California Management Review*, v.33, n. 3, p.119-135, 1991.
6. INTERNATIONAL ATOMIC ENERGY AGENCY, *Knowledge management for Nuclear Research and Development Organizations*, Vienna, 2012. IAEA-TECDOC-1675.
7. RICCIARDI R.I., BARROSO A.C.O. & J.L. ERMINE Knowledge evaluation for Knowledge Management Implementation: a Case Study of the Radiopharmaceutical Center of IPEN. *Int. J. Nuclear Knowledge Management*. vl.2 n.1, p. 64-75, 2006.