Explicit Knowledge Management on the Product Development Process

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Abstract: The knowledge management has received great attention from professionals and specialists who work with the product development process. The activities of this process have an essential creative character and, therefore, depend basically on the knowledge of the people who perform them. A significant part of this knowledge is stored in the form of explicit knowledge, that is, structured documents that contain experiences and information of the development of the product. To manage them adequately contributes to the knowledge management effort. In this work the form of recording of explicit knowledge is analyzed and an architecture proposed that supports the development of systems capable of managing them efficiently, that is, in ways to contribute to improvements in the business process. Three large stages were used: a bibliographical review of the subject; the proposal of architecture for the development of these types of systems; and the development of a tool to verify the viability of the architecture. In the end apart from the proposed architecture the importance of using a conceptual model for the specification and development of management systems for explicit knowledge is demonstrated.
Keywords: Knowledge Management, Learning Organization, Knowledge Management Tools, Explicit Knowledge, Product Development Process.

1. Introduction

The product development process (PDP) can greatly benefit from the knowledge management as the activities that consist of it have an essential creative character and, therefore, depend basically on the knowledge and abilities of people that perform them. Moreover, the productivity and quality of the final project can be improved by the intensive use of techniques and methods, which have experience as a decisive factor for the success of its application. An efficient knowledge management should allow that the adopted solutions and experiences in each project can be spread out through the organization, allowing continuous improvement of the performance of the company in this business process.

Part of the knowledge of an organization that develops products is stored in form of documents (reports, drawings, test results, minutes, books, etc.) and material that can be stored and offered to a variety of people who are part of it; this represents explicit knowledge. One of the forms to contribute to the Knowledge management is creating tools that help the management of such types of knowledge.

These systems received great attention during the up coming of the field of knowledge management and were in the beginning equivocally held as definitive solutions in the area. It is evident that they contribute, but they are not enough. The effective knowledge management depends on many other aspects such as: culture, motivation, ability, among others.

On the other hand, it must be recognized that these systems are an important part of the solution of the problem without disregarding its benefits. Besides being instruments that help and speed up the exchange of knowledge between people, they have the potential to act as catalyst in a possible effort to improve the Knowledge management, that is, when its implantation serves as motivation and orientation for members of the company in their necessity of working on this subject.

Thus it is of basic importance to improve them mainly in dealing with PDP. The multidiscipline and ample character and the necessity to work in teams present in this area makes it difficult to access the great amount of explicit knowledge that is produced in each project.

Three big problems are especially important in view of the management of explicit knowledge in the PDP. The first two are the difficulty to validate and systemize stored explicit knowledge. The third aspect is how to make use of the great amount of IT solutions available. Many of the these solutions are mere generic tools that already existed in the past and that are commercialized without showing the context of its application in a wider sense of knowledge management. They are electronic document management systems (EDM), systems for long-distance education, among others, that, certainly, carry functions which assist in the Knowledge management, but they need to be analyzed in terms of advantages and disadvantages, including how to combine the available functionality in these different system categories.

Trying to contribute to the solution of these challenges this work aims at the proposition of architecture for the development of a management system for explicit knowledge on PDP. This architecture is basically a conceptual model that guides the development of systems that contribute effectively to the management of explicit knowledge in PDP. The solutions based on this architecture can be developed using different solutions and available computer technologies, including a system for validation and systematization of knowledge.

In item 2, bibliographical review, the basic concepts of knowledge management and an analysis on the main form of recording explicit knowledge is shown. In item 3, the methodology used in the development of the work is presented, and in item 4, the proposed architecture described. Item 5 shows how to use the architecture and last, item 6 presents the final discussion.

2. Bibliographical Review

2.1 Knowledge Management

To define and locate knowledge, DAVENPORT & PRUSAK, 1998, differentiate between three great element groups that are:

Data: which is a discrete and objective set of facts on a specific event. It is therefore the quantifiable and objective part of the information supply and knowledge of a company and is usually stored in databases or documents of the company (Example of data: temperature of the atmosphere 32 degrees);

Information: a message that contains a sender and a receiver and whose meaning involves a new interpretation based on a set of data. (Example: due to temperature and atmospheric pressure it should rain in an hour). In every company there is a complex and continuous stream of information either through technological means as computational systems or by means of interaction between people;

Knowledge: is a flowing mixture of experiences, values, contextual information and intuition building a framework (a panel) in the mind of a person which qualifies him to evaluate and obtain new experience and information.

2.2 Types of Knowledge

NONAKA & TAKEUCHI, 1995, achieved an important distinction of types of knowledge that has been widely employed. The authors define:

♦ **Explicit Knowledge**: is the knowledge that is structured and capable of being verbalized. Therefore, it is the structured and objective part of knowledge. The one that can be stored in documents and computational systems. Part of explicit knowledge is: norms, bibliographical records, books, work procedures and others;

♦ **Tacit Knowledge:** is the knowledge inherent to people, that is, the abilities that this person possesses. It is therefore the non-structured part of knowledge that cannot be recorded and/or easily transmitted to another person.

These authors suggest the existence of a continuous cycle inside the companies where explicit knowledge is transforming into tacit and vice versa. This cycle is represented as a "spiral of knowledge". In this view, the role of the Knowledge management is to guarantee and to help the free flow of the cycle in all the organization. Thus the Knowledge management has not only the role of taking care of the infrastructure for the record and organization of explicit knowledge but also to guarantee the environmental and intellectual condition of the people necessary for the maintenance of this cycle.

2.3 Explicit Knowledge Codification

Codify the knowledge is to put it into a form that makes it accessible to those who need, in other words, to represent it. There are different forms to do these representations. The most traditional and best know are books, internal documents, cooperative systems and databases spread through the company. In this article they are generically called not standardized.

A more specific way of storing explicit knowledge is the construction of Knowledge Maps which are records that points to knowledge, that is, the people, documents and databases (DAVENPORT & PRUSACK, 1998). The map itself is an explicit knowledge that enormously helps in the process of transformation and broadcasting of knowledge as it allows that people identify the sources of explicit knowledge and, moreover, the people who "carry" some tacit knowledge. An efficient map should be constructed in agreement with the features of the organization and should show internal as well as external company knowledge.

Another form is the creation of Narratives, that means having the members of the organization record stories on events on a certain project or activity. According to DAVENPORT & PRUSACK, 1998, this is an interesting way of storing knowledge closest to being tacit, meaning more unstructured. This is because telling stories is quite a natural and easy way for a person to display and to demonstrate certain complex knowledge. However, the authors do not mention that even though it helps the record this format has an inconvenience: an increase in difficulty of the search (how to find knowledge which is implicit in the record) and the necessity of a greater effort in interpretation.

The third form is the creation of explicit knowledge based on structured language. In this format knowledge is recorded in a language formed by the current language adding restrictions and norms that make texts less ambiguous. Such as the English-Like used in the area of system analysis. Quite similar is the record by means of rules (norms), quite like the production rules in the Artificial Intelligence and Specialists Systems area (see RODGERS et al.,1999). In these formats knowledge is recorded as a set of interrelated rules that by being structured becomes less ambiguous and easier to locate. However, to execute the record in form of rules becomes more difficult according to knowledge complexity increment.

Explicit knowledge can also be represented by an ontology which is a set of explicit and unambiguous specifications of concepts related to a specific domain (see STUDER, BENJAMIN & FENSEL 1998; O'LEARY,1998; DIENG et al, 1999). Ontologies are also used as help in the construction of reference models, which can also be considered as a way of representation of explicit knowledge (ABECKER et al, 1998; DIENG et al, 1999).

2.4 Tools for Knowledge Management

Based on one or more of theses representations means, various systems to store knowledge management have been suggested. They vary from more pragmatic solutions limited by storage and search functions to more complex systems from the field of Artificial Intelligence and Specialist Systems. The main distinction between these two "poles" refers to the creation of inferences. While the latter use sophisticated features of the computer technology to create inferences automatically, the former are tools that are limited to record and storage leaving analysis and inference up to the human user.

MATTA, CORBY & PRASAD, 1998, propose a generic library for the development of record systems about conflicts in activities of simultaneous engineering. In this proposal explicit knowledge is recorded in the form of cases containing structured texts for a limited set of attributes.

In the line of specialist systems, RODGERS et al, 1999, show an example of the development of a system based on rules, called WEBCADET, to record knowledge in face of a concept inside the process of product development. On the other hand, REIMER, 1995, presents the EULE2, a system destined to record and manage explicit knowledge in offices and which uses a structured language, but moreover, integrates these rules with what he calls organizational memory, that is explicit unstructured knowledge like different documents and texts.

DIENG et al,1999, presents a review on techniques and methods for recording explicit knowledge called by them organizational memories, where they cite three other concept systems not presented here: CYGMA, REX and MKSM. In their analysis they conclude that the trend that should be followed for systems of organizational memory is the use of more than one of the forms of knowledge representation.

An example of the use of multiple representations is the proposal of ABECKER et al, 1998. The authors propose a model of three layers represented by a pyramid. The inferior layer at the base of the pyramid is called object level and contains not standardized explicit knowledge and cases in form of narratives. The second layer, superior to the object level, is the descriptive level, which contains ontologies that summarize, contextualize and guide the user in view of knowledge recorded in the inferior layer. This level has as objective to perform a precise selection and control of access to the information and to increase the understanding of the user in view of the interpretation of explicit knowledge in the object level. At the top of the pyramid there is the application layer that contains explicit knowledge in form of reference models and has as objective to help in the search of knowledge and to supply the user with the context, in terms of stage and activity of the business process, that the explicit knowledge should be used.

These proposals, mainly the ones that integrate different forms of record, are quite promising but are still not robust and pragmatic enough. The majority of them are limited to only one format of explicit knowledge. Moreover, they suffer from two main problems: the creation of flexible record and search systems; and the method for validation (priority and relevance) of records.

The non-existence of a validation method exposes the system to the risk of becoming obsolete in the short term because of accumulation of irrelevant knowledge by users. This kind of the knowledge makes the search difficult and, if incorrect, promotes insecurity about the legitimacy of the rest of the stored knowledge. At the same time, if methods become too complex (bureaucratic in the pejorative meaning of the term), this could discourage people who record explicit knowledge. In this sense, SILVA & ROZENFELD, 1998, relate the interesting experience of a multinational company at autopart industry. The company installed a sophisticated record system of explicit knowledge during product development which (called Best/Bad Practice) was very little used. The authors showed that the main reason for not using it was the difficulty of suggesting and validating new knowledge. The user had to assemble a large quantity of documents to submit a new Best/Bad Practice. This suggestion was then analyzed by an international committee and, when approved, recorded in the system. Consequently, a lot of people in the organization who had explicit knowledge long used by them did not submit it for appreciation to include it to the system due to the necessary effort to run this complex flow.

There is still the question of the easiness of use, an important point to stimulate people to share knowledge.

Besides the mentioned proposals, which are results of scientific research, there are a lot of commercial solutions under the label of knowledge management tools. CARVALHO & FERREIRA, 2000, analyzed these solutions and showed that they lead towards turning suites, that is a group of various tools that need to be personalized (customized) by the user. It is evident in this work that those tools, however, have distinct origins and carry essentially a wide collection of functions connected to the management of documents and databases. They are the result of the tendency of different software manufacturers that take advantage of the commercial appeal that knowledge management has inside companies. Therefore it is clear that a great barrier in the application of solutions turns out to be how to define the best format of storing and the definition of what are the necessary functionalities for managing explicit knowledge inside an specific organization. Once these formats and functions are defined, tools can be chosen that can provide them at the lowest cost and best efficiency.

By this situation the development of a concept model was started that contains a group of elements and which supports the development of solutions for the manage of the explicit knowledge on product development process. This model, called Architecture, contains the following features: to use the commercially available tools, to consider the different forms of explicit knowledge, and to contain a system for validation and systematization of stored explicit knowledge.

3. Methodology

The objective of this work is to present an architecture for the development of systems for the management of explicit knowledge on the product development process, using the commercially available tools. It is a kind of research-action in which to find out the viability of the creation of such model, this itself was developed by the researcher and tested by means of construction of a specially designed tool based on that architecture. For this the following stages were performed:

♦ Bibliographical review: analysis of the different forms of representation of explicit knowledge and of the difficulties and virtues of the different tools for the management of the knowledge;

♦ Proposal of an architecture: proposal of an architecture for the creation of systems of explicit knowledge management based on bibliographical review; and

♦ Development of a tool prototype: development of a tool prototype using the architecture previously proposed.

4. Architecture for explicit knowledge management on the product development process

4.1 Basic Principle

The model of NONAKA & TAKEUCHI, 1995, about cycles of transformation of knowledge, presented in item 2, bibliographical review, was used as basic principle for the development of the architecture. In this reference, to intervene in the knowledge management means to perform actions that create the necessary conditions for the continuous transformation of knowledge through organization (from tacit to explicit and vice versa) with the intention of attaining improvements in the work process and products.

The role of the tools of information technology is to support the transformation that occurs during the different stages of the cycle. The tools must furthermore guarantee integration between these stages and allow that systemized knowledge can be restored and combined in another stage, either when carried out by the same or by a different person.

The choice of this reference was motivated as seeming the most practical for the performance in the area of knowledge management. It allows a clear definition of the performance target and is in harmony with the concept of learning organization. This can be noticed by analyzing the basic idea behind this principle. It is not the tool, the training or the people itself that guarantee separately the effective knowledge management. It is, in fact, the existence of this cycle that allows the creation and continuous transmission of knowledge from person to person inside the organization. Consequently, the effective knowledge management is the effort of maintenance and strengthening of the cycle. It is up to the organization interested in improving its Knowledge management to create the environmental conditions (means, values, motivation, etc), to supply training and qualification, among other actions, to create a proper environment so that this cycle is always being reinforced inside the organization, creating an accumulation of knowledge in the company and reflecting real improvements in business deals and products.

Another important point of this reference is that it well defines the role of IT tools in the Knowledge management. The stages of the cycle to more or less be supported by these tools. In some of them the impact of these tools is insignificant. So, a IT tool whatever, including the here proposed architecture, is separately seen insufficient for the achievement of an effective knowledge management in an organization. They are more or less important parts of the solution according to type and size of a company. They take part in the solution and are not a guarantee of an effective Knowledge management.

4.2 Requirements

Based on this reference and the barriers of the implementation of knowledge management identified in the bibliographical review the following requirements were defined to the architecture:

1. To support stages of the conversion cycle: the architecture should record and manage explicit knowledge by means of supporting the four stages of the cycle of knowledge conversion, doing this in the most efficient way.

2. To support the integration between the stages of the conversion cycle: it should allow that the explicit knowledge created by one person in a certain stage of the conversion is available to other people who are at the same or any other stage of the conversion cycle.

3. To possess systematic methods for validation and systematization of stored explicit knowledge: the architecture should have systematic methods for validation and systematization of explicit knowledge so that the recorded knowledge can easily be accessed even in the face of a great volume of available information.

4. To support the creation of process models: it should allow to create reference and specifics models for the product development process using stored explicit knowledge.

5. Integration between process models and explicit knowledge: it should keep the integration between reference models and explicit knowledge: from the model it should be possible to visualize the explicit knowledge that has served as base for its use and vice versa.

6. To manage a set of reference models for different types of product development processes: it should allow that reference models are created which consider the peculiarities of the product development process.

7. To incorporate a modeling methodology and to allow the comparison of models: to possess a modeling methodology so that reference models can be created in a standard form helping comparison between models.

4.3 Description of the Architecture

An architecture overview is represented in figure 1. On the left side is shown in a simplified way the cycle of conversion of knowledge that was used as basic principle on which the architecture was based. In it is shown that the main objective of the tools based on the architecture is to support the execution of the stages of this cycle and also to help integration between them. Furthermore it is seen that the architecture is built by three categories of main elements that appear in gray in the figure: a explicit knowledge repository, specifications and a set of support elements. The latter are models that describe specific aspects and that should be used as base in the implementation of the functions.

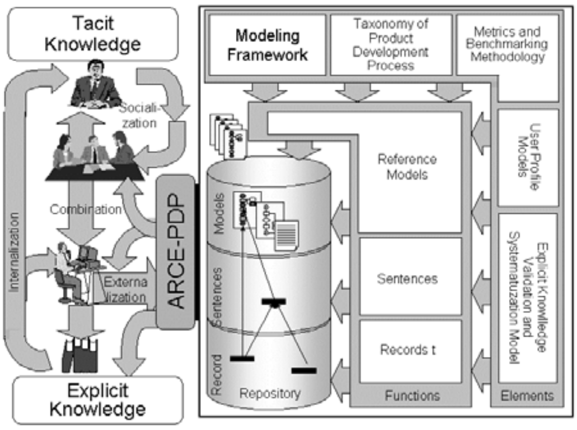

Figure 1 – Architecture Overview

As to the cycle of creation of knowledge, the stages that are most strongly supported are externalization and internalization. In the externalization, when occur the transformation of tacit knowledge into explicit, the architecture assists in helping to record and to store explicit knowledge. It should also assist the internalization by supporting the search and identification of relevant explicit knowledge which could be used by the individuals and transformed into new tacit knowledge. Another important role of the architecture in the cycle is the integration between these stages, mainly when performed by different members of the organization. It allows that explicit knowledge externalized by one of the members can be located and used by the other members of the organization.

The architecture can also assist in the combination stage in which explicit knowledge is combined resulting new knowledge. This helps in the search, identification and presentation of different explicit knowledge to be put together. In this stage it also helps the recording of the received explicit knowledge. One feature of the architecture that can help in this stage is the incorporation of the view of enterprise models. This concerns a type of explicit knowledge that represents the whole product development process forming a widely view of it. This view can help to retrieve the explicit knowledge, enabling the combination with other knowledge.

As to the stage of socialization where tacit knowledge is transformed into tacit knowledge, the architecture has little to offer, as demonstrated in the figure. This stage of the cycle depends basically on interaction between people. Computer tools are limited to supporting in the search and identification of people who have a certain knowledge or ability.

Analyzing the inside of the architecture (right hand box) one notices initially that it is formed by three groups of objects: repository, functions specifications and support elements. The repository is a model that specifies how the explicit knowledge should be stored. The second group of objects specifies which of the functions to be put out from the system for maintenance of the repository, and finally, there is still a set of support elements formed by models that guide the specifications of such functions.

The repository stores explicit knowledge in three basic types called: records, sentences and models (see figure 1). Records are all the documents that are create during the product development process such as meeting minutes, designs, procedures, cases, book references, reports among others. Sentences are a specific kind of so-called structured knowledge with a standard format. Each sentence represents a specific idea in the form of rules with a subject and a verb. Sentences are created from records. They represent ideas that are incorporated in one or more of them. Such ideas are presented jointly for evaluation of their approval rate by means of an index computed from a systematic evaluation of the explicit knowledge that supports the sentence. This index and form of validation are specified in the “Model of Validation and Systematization of Explicit Knowledge”, one of the support elements that integrate the architecture. Sentences are a fundamental part inside the concept of validation and systematization of knowledge. Finally, there is the knowledge represented in the layer of the highest level, the models of the product development process. They are representations of the process and that is why they form the upper layer of the repository indicating that they "carry" in themselves a systematic view of the process, which helps in the of the stored explicit knowledge below.

Furthermore, there is the possibility of establishing relationships between these different types of knowledge. While doing so, "surfing" between explicit knowledge is allowed and also to trace which records have been used as base for the creation of the sentences, and also, which records and sentences have served as base for the decisions of the model.

The architecture is furthermore composed of functions that have to be implemented for the creation and maintenance of the repository. These functions cover from registration, storage and update of explicit knowledge to their handling, including addition of comments, comparisons, validation, classification and others. It contains a set of functions for each type of stored explicit knowledge.

The architecture still foresees a set of 4 conceptual elements which define how to implement the above specified functions. These elements support the registration, classification and organization activities of explicit knowledge. A modeling framework, a typology of product development processes, metrics and methodology of benchmarking, a model of the user profile and a model for systematization and classification of explicit knowledge; they are shown as boxes next to those of the functions in figure 1.

The model of systematization and validation of explicit knowledge is fundamental for the handling of the great amount of explicit knowledge that should be created by application of the architecture. Without this element access to explicit knowledge could be difficult because of the amount of records. It specifies how to organize and classify records and how to create the second layer of the repository: the sentences. Each sentence is related to one or more records and summarizes a specific idea, therefore the sentences synthesize a set of records. By means of an evaluation system with indexes, foreseen in this model, the user is supplied with an indication of approval or disapproval of certain knowledge.

Once put into a hierarchical order, the explicit knowledge can also be related to reference models. At this stage the element-modeling framework should allow the creation of process models in standard form. This standardization should help to compare models and their maintenance. Although the possibility of standardization exists, it is not mandatory, therefore registration of models is possible independent of the representation form and modeling tool. And each created model is classified according to the Taxonomy of Product Development Processes (ROZENFELD & AMARAL, 1999) allowing to qualify the main features of the process for which the model was designed. This information is essential the moment when the model is applied or when it is used as base for creating others. And it is at this moment of comparison and creation of new models that the element Metrics and Methodology of Benchmarking supplies subsidies to help in this activity.

There is still a Model of User Profiles that specifies the permission of the different users' types and should be used as base for the implementation of functions connected to the access control.

5. Using the architecture

The architecture as described in this chapter should support the development of systems of explicit knowledge management. To make use of the architecture means, ultimately, to use the specifications contained in these elements of the model as guide for the design and construction of a specific system using specified solutions and/or available computer technologies.

The model of the repository, functions and support elements form a set of specifications of a high level whose details, as for example the amount of areas to describe each type of record and the division of knowledge in group and subgroups , can be defined in agreement with the features of the company for which the system was developed.; even though there is a basic proposal in the support elements of the architecture.

At this level of abstraction these specifications are independent from the information technology, therefore can be implemented using one or more solutions and technologies of IT, that then can be chosen according to the available solutions and special features of the company. This is a strong argument of the proposal of this architecture. By virtue of this the architecture can be used in many ways. From the development of a new sophisticated tool that contains all this explicit knowledge to being used as guide for the integration of already existing document management solutions presented at this company. In this last case, even simple procedures are employed that do not use computer technology.

For example, a possible way to implement the architecture would be the use of a simple modeling tool (that contains only features of graphical design like VISIO) to create models and store them in folders in the network. The various record type documents could also be stored in the network of the company controlling the access through the operational system (for example using the users' manager of Windows NT). And to control registration of records and sentences a simple relational database system can be used (like ACCESS or SQL Server). Thus the users would search in these simplified systems and could get the file names with the explicit knowledge and their location inside the web, either records, sentences or models. With this information they could access them. In this possible implementation both the modeling framework and the taxonomy for classification of models would be described in specific documents also available in the web. Thus any doubt as to describe or prepare the company model would be enough to consult them.

On the other hand there could be an implementation using two more sophisticated commercial solutions: a modeling tool and a tool of Electronic Document Management or Product Data Management. Being more sophisticated systems they would make the development of an integration possible so that the models created with help of the modeling tool could be controlled directly by the document management system. With this it would be possible to set the document management system to store records, sentences and models in an integrated way as specified in the architecture. Besides the search and registration of each explicit knowledge in the system there would be direct access to the document containing explicit knowledge. With the integration between models and records, both controlled by the system, access to process models would be allowed. Another important feature is that the modeling tool could be customized to develop models according to the proposed modeling framework. It would be enough that the specifications of this framework were verified by the system hindering the construction of non- standard models.

To evaluate the architecture a prototype of a solution was developed. This solution uses a "family" of desktop systems (Microsoft Office), an intranet (developed using technology Active Server Pages, ASP , and a relational SQL Server base) and a modeling tool (ARIS TOOLSET). The setting of the tool can be seen in figure 2.

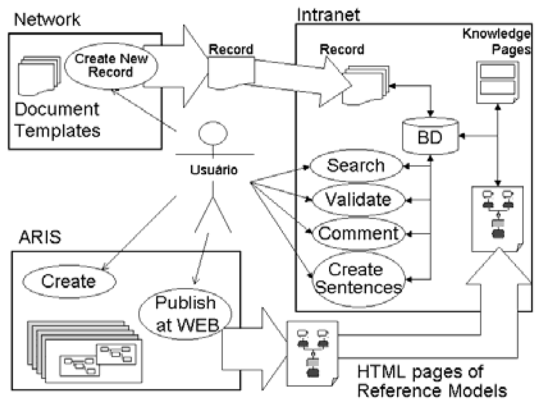

Figure 2 – Context Diagram of Solution

Figure 2 demonstrates that the records created during the product development are stored in the network of the company using desktop appliances (OFFICE). These appliances in turn help the registration of records in the database of the intranet (see figure 2). In the same way the process models are created and published in form of pages which incorporate the intranet. Therefore, the user could search the intranet and comment each record and model. Moreover the user is allowed to insert sentences and validate explicit knowledge according to the systematic foreseen in the architecture.

Figure 3 shows the main screen of the knowledge intranet with four modules: Practices (where the records and sentences are registered and listed); Reference Models (where the reference models are registered and listed); People & Knowledge (where information on the users of the system

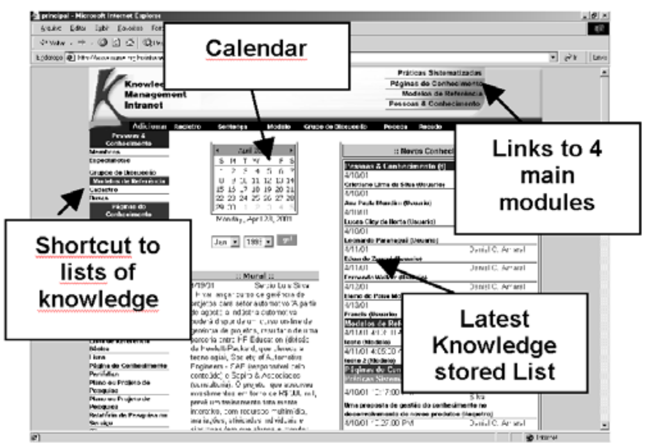

Figure 3 – Tela Inicial do Protótipo

and their knowledge and experience can be accessed); and Knowledge Page (that contain pages describing a summary of the recorded explicit knowledge).

The complete solution (intranet, modeling tools and network) started to be tested and the initial results show great potential.

6. Final Remarks and Conclusions

To manage in an efficient way the explicit knowledge acquired during product development is a fundamental question for professionals who act in this process. In this work different forms of recording explicit knowledge and the main barriers of commercially available tools for this purpose were presented. Based on these analyses architecture was suggested which is capable to support the development of those systems that try to supplant the main barriers shown above. To test this architecture a system based on its concepts was also developed. The results of the development of the shown solution acquired with help of the architecture and the first evaluation of this initial prototype are quite promising. The architecture really helped enormously in the development of the solution guiding its specifications and developments well enough. Moreover, it worked in such a flexible way that it was possible to create a solution using already existing commercial and simple developer tools.

This solution allows to integrate the stored explicit knowledge in a view of processes and allows an orientation for action because this knowledge is directly related to reference models which guide the product development of a company.

Therefore, the most important result of this research was to demonstrate the viability and importance of creating concept models which help the "customization" of knowledge management tools available on the market. In the future it is expected to continue research in this area carrying out new applications and more intensive tests of the developed solution; and improving continuously the proposed architecture.

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