Knowledge Management in Learning Environment Design

Inés Friss de Kereki[1], Javier Azpiazu[2], Andrés Silva[3]

Abstract **- Knowledge management can be seen as the process of integrating information, to get sense out of incomplete information and to renew it. Codification converts knowledge into accessible, applicable formats, making it as organized, explicit, portable and easy to understand as possible. Communities of practice are groups of people who have practice and knowledge in common. These related concepts -knowledge management, codification and communities of practice- are applicable to learning, since learning involves acquisition and modification of knowledge, skills, strategies, attitudes and behaviors. A learning environment is the space where it is possible to manage knowledge or, rather, ignorance. We propose a new model, based on knowledge management, codification and communities of practice. We analyzed different models but did not find a learning environment with these characteristics. We developed an environment applying the model. Students who used it show remarkably improved problem solving skills and better capacity to transfer knowledge from one situation to another.**

Index Terms - Knowledge Management, Learning Environment, Learning Mode.

KNOWLEDGE MANAGEMENT

Knowledge Management (KM) is somewhat old and somewhat new at the same time, it is the combination of new ideas with the ideas 'everybody knows of old' [1]. Davenport [2] refers to procedures that drive KM in daily process: how knowledge is created or how it is obtained from employees, how it is distributed and accessed and how it is transferred to other people and applied to business problems and decisions.

In a more formal way, KM is a framework and a set of tools to improve an organization knowledge infrastructure, aiming to furnishing the right knowledge to the right person in the right way and in the right moment [3]. The grounds for KM are: exploring knowledge and its adaptability, finding the value of knowledge and actively managing knowledge [4]. KM may be considered as the process that a) Integrates information (accessing, organizing, storing, searching, recovering, navigating, codifying, referring, categorizing and cataloging it); b) Draws some sense out of incomplete information, and c) Updates information, ensuring its continuity through manual procedures, supplemented by information technologies tools [5].

I. Corporate Memories

Corporate or Institutional memories (CM) are a fundamental tool for teaming up people and technology. They support knowledge sharing and the reuse of individual and institutional knowledge, of learned lessons and of best practices, according to Paradela [5].

Van Heijst and colleagues [6] define CM as an explicit, disembodied, persistent representation of the knowledge and information in an organization. This includes knowledge about products, productions process, customers, marketing strategies, financial results, etc. According to Nagendra Prasad and colleagues [7] CM consists of all the information and knowledge resources within an organization. It may include company databases, machine-readable texts, reports, product requirements, etc.

To summarize, CM primary function is to enhance institutional competitiveness by improving the way in which knowledge is managed. This definition may be extended to an educational context.

II. Codification

'The aim of codification is to put organizational knowledge into a form that makes it accessible to those who need it'[8]. More precisely, codification converts knowledge into accessible, applicable formats, making it as organized, explicit, portable and easy to understand as possible [8][9].

The main difficulty in codification is how to codify knowledge without losing its distinctive properties. Davenport and Prusak point to some principles to codify knowledge successfully. Two of them are evaluating knowledge for usefulness and appropriateness for codification and identifying an appropriate medium for codification and distribution [8].

III. Communities of practice

'Communities of practice (CP) are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis' [9]. As Brown and Duguid say [10]: if you become a member of a community and engage in its practices, you can acquire and use its knowledge and information.

These related concepts -KM in general, codification and CP- are applicable to learning, since learning involves acquisition and modification of knowledge, skills, strategies,

[1] Inés Friss de Kereki, Engineering School, ORT Uruguay University, Montevideo, Uruguay, kereki_i@ort.edu.uy , kerekii@adinet.com.uy
[2] Javier Azpiazu, Computer Science School, Polytechnical University of Madrid, Madrid, Spain, jazpiazu@fi.upm.es
[3] Andrés Silva, Computer Science School, Polytechnical University of Madrid, Madrid, Spain, asilva@fi.upm.es

attitudes and behaviors [11].

LEARNING ENVIRONMENTS

A learning environment (LE) is the space where conditions are established in order to let the individual acquire new knowledge, new experiences and new elements, and to generate processes of analysis, reflection and appropriation, according to Avila and Bosco [12]. The environment must fulfill student's expectations. It must also be based on the students' participation and responsibilities. It has, moreover, to consider the different kinds of intelligence [13]. According to Hiltz [14] the environment must be effective and efficient presenting concepts from different points of view, showing different examples and providing self-tests.

For this paper, the following definition of a LE is proposed: A LE is a space that is adaptable (capable of recognizing student's cognitive skills and learning preferences) to benefit student's independent work, so as to offer non sequential approaches to promote the free linking of ideas. It implies that students be the center and that the students themselves choose and make their own paths, without the strictness of an inflexible schedule or a pre-established working order.

I. Different LE models

From among the multiplicity of environments and LE models, a few that seemed to be more appropiate were selected, though this selection may be questionable and idiosyncratic.

The IEEE P1484.1 standard [15] describes the high-level system design and the components of a Learning Technology Systems Architecture (LTSA). The components of a LTSA system are: processes (learner, evaluation, system coach, delivery process), stores (records database and knowledge library) and information flows (behavior, assessment, learning info or performance, query index, content index, locator index, learning content, multimedia, learning style or preferences).

Wiig [16] describes an effective teaching model. The teaching process starts with a practical example; the next step is the introduction of a more general case (script) in order to show that a wider field exists. The case is then expanded, so as to obtain an initial scheme to present general characteristics. A new example, different but congruent with the previous scheme, is afterwards presented. The stages are repeated.

Azpiazu and colleagues [17] propose tele-formation and the virtual classroom. Tele-formation or tele-teaching allows flexibility of time and space and encourages self-learning. A rigorous didactic and pedagogic design and a correct use of technological resources are needed, as well as the creation of academic memories to answer questions automatically and a suitable personalized assistance. As a disadvantage, it may be pointed out a lack of interaction between students and teacher. The virtual classroom should provide an education centered on the resolution of problems and search of solutions. The professor would act as a guide.

Ghaoui and colleagues [18] present an extensible model called ExAM, that allows eliciting, extension and knowledge storage, starting from conceptual information contained in teaching media. They focus on the benefits of object oriented methodology for the construction of materials in order to generate multiple views.

The model proposed by Gil [19] offers a didactic guide that includes an introduction or role of the subject inside the studies, objectives of the course, requirements, methodology, didactic materials, tutorial support (face to face and telematic), evaluation approaches, graphic interface, contents of the course, structuring of contents and recommendations for its study. It should also have useful links, a forum for the asynchronous communication between students, FAQ (answers to most common questions), questionnaires for evaluation of the process, diverse materials and self-assessment activities and hetero-assessment.

Other environments were analyzed, such as COSE [20], TANGO-W [21], Hypermedia [22], ID Expert [23] and the extensive list offered by de Benito [24].

II. Opportunities for improvement

Some opportunities for improvement of the offered models are found. Related to the IEEE P1484.1 standard [15] the opportunities are: a) A definition for learning-resources-structure, which is lacking; b) Establishing a direct relation between the learner entity and learning resources. Students should be able to access those resources directly, according to their own preferences; c) Including an additional module for supporting KM as, for example, a corporate or institutional memory or yellow-pages (a directory of experts for each topic); d) A teacher entity, which is not modeled; and e) Allowing a space for students' assessment of the knowledge repository. Those ideas have been posted to the IEEE LTSC working group [25], but up to date there has been no response.

Wiig's model [16] does not allow for the different learning styles [26] or for students' special characteristics [21]. Moreover, in Wiig's model [16] an ordering is established for knowledge, without any other options. Azpiazu and colleagues' virtual class [17] manages knowledge and describes its components in too general a form. A low level structure and room for the already mentioned different learning styles are not included. Also, other KM elements such as yellow pages are not considered.

The ExAm model [18] uses a bottom-up approach, as it first identifies concepts and then extracts and generalizes common properties. Formalization of the different knowledge types (which might be viewed as a top-down approach) is missing, as well as any specific reference to learning styles in the formulation or modeling of knowledge. Gil's model [19] offers a guide for presenting contents, but its order might limit students as they cannot select their own order or method.

Summing up, until now, no LE with the characteristics of the proposed one was found in the bibliographical research we carried out. Detected problems in those environments are that many times there seems to be an excess of information and that the environments are not centered on the student. None manages knowledge explicitly (except for [17]). Management of knowledge is an ever increasingly needed feature, when the characteristics of the knowledge society and its ever expanding knowledge are considered.

THE MODEL

The proposed model of a LE (see Figure 1) will consist of: student entity, professor entity, supervisor process and KM module.

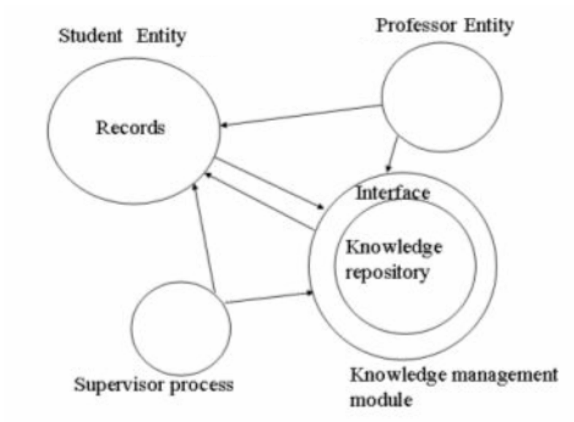

FIGURE 1
MODEL ARCHITECTURE

The **student entity** represents a student or a group. When interacting with the environment, through access to the KM module, a 'portfolio' or 'portfolio of works' containing a log of the activities performed and learning preferences is recorded. This information may be used by the intelligent tutorship. The student entity can collaborate in the evaluation of the types of knowledge, is able to reclassify them as needed and, if necessary, may incorporate learned lessons. In this way, he participates in the learning CP.

The **professor entity** participates and interacts directly with the KM module, defining and restructuring it according to the students' use of the environment. In this way the professor is able to adjust the contents of the KM module.

The **supervisor process** carries out the intelligent tutorship, observing the user actions and suggesting action roads according to the user preferences. For example, if a student prefers certain types of knowledge, when facing new requirements knowledge of that same types could be offered.

The **KM module** includes the knowledge repository (institutional or academic memory) with the codified knowledge as well as an interface to easily 'navigate' it. The knowledge in the KM module is codified in:

? **heuristic knowledge (HK).** Examples are best practices, learned lessons, frequent and unfrequent questions and the yellow pages.
? **descriptive knowledge (DK).** It is a concept or an idea, the knowledge with which a situation is described.
? **procedural knowledge (PK).** It is the knowledge required to take an action. It describes a procedure or a process.
? **anecdotal knowledge (AK).** It refers to anecdotes, histories and stories linked to a given knowledge.

DK could be alternative, basic, enlarged, comparative or monitoring. The *alternative* DK represents the bonds to other versions of the same concept, ideas or situation. The *basic* DK represents an initial form of DK. In turn, the *enlarged* DK presents a descriptive knowledge in a more general way, the *comparative* DK describes a knowledge as compared with another. *Monitoring* is an exercise for checking the understanding of a descriptive knowledge.

PK could be basic, replicant for analogy, monitoring or alternative. The *basic procedural* knowledge represents the fundamental procedural knowledge. The *replicant* for analogy is knowledge that may be obtained as a replication of another by means of analogy; that of *monitoring* is an exercise for checking the understanding or application of a concept, idea or procedure, and the *alternative* PK is another form of carrying out a procedure.

The format of each component of the module of KM is:

Describer	Knowledge	Counter

The *describer* is one of the values: HK, PK, AK, DK. The *knowledge* refers to a knowledge object. Each knowledge object is linked to other types of knowledge. The attributes of knowledge are: description, learning strategy [26], importance (fundamental, non fundamental), medium (text, video, sound, multimedia), required level (basic, medium, advanced), responsible professor and topic. The *counter* tallies the number of accesses to the record. With the counter, the system is able to reclassify a question or to decide which are the most consulted knowledge objects. For example, at the beginning of a new course, such a re-classifying could be made.

In the knowledge repository, all of the knowledge that the professor considers necessary will be initially stored. For gathering the knowledge requirements, techniques of knowledge engineering, such as interviews, analysis of protocols and observation, as well as techniques used in the area of software requirements engineering might be used.

I. Model contribution

When compared the proposed model with the IEEE P1484.1 [15] standard, the main differences or contributions are: a) A structure for learning resources (in the knowledge repository) is defined. Those resources are centered on knowledge types; b) A direct relationship appears between the learner entity and learning resources, because the students may access the resources directly, therefore managing their knowledge and/or ignorance; c) A new module: the KM module. It also contains the institutional memory which will be used and updated by students and teachers alike; d) A teacher entity is incorporated; and e) Assessment is contained within the KM module itself. The students' assessment of the knowledge repository itself is included. The principles suggested by Davenport and Prusak [8] are taken into account.

If compared with Wiig's model [16] or Gil's model [19] it is observed that no pre-established order is fixed. It incorporates the whole module of KM, a feature not detailed in Gil's proposal. Also, learning styles are considered because material may be presented in many forms and media, allowing access according to student preferences [26]. It includes and enlarges the components of the virtual classroom [17]. Different types of knowledge are formalized [18] and it is centered on students and KM.

II. Application

The model was applied and evaluated in a basic course of Object Oriented Programming for freshmen students of systems engineering at ORT Uruguay University. The implementation –called PLE:ASE (Programming Learning Environment, an Approach to Software for Education)- was carried out in Java. Inside the system, a hierarchy of classes was modeled for the knowledge and a class was used for each type of knowledge. To simplify the teacher's data entry, knowledge may be uploaded from plain files or from within the system itself.

The system records students activity; this activity may be printed or consulted through the system itself. The intelligent tutorship monitors students actions and may suggest the most appropriate strategy, according to the learner's preferences. For the intelligent tutorship, a basic follow up was made, that is to say, by means of the actual teacher (or teaching assistants) support. The students may contribute new elements, integrating their personal skills to the group.

As an example of use, let us present the following scenario. The student logs into the system and then a list of available topics is displayed. In this simplified case: Classes, Arrays and Inheritance. He chooses 'Classes'. Afterwards, a list of available knowledge related with this topic appears: basic DK ('the definition of a class') and basic PK ('describes the procedure to define a class'). When the student chooses 'basic descriptive', the definition of 'class' appears and also some options (see Figure 2). For instance, AK (which presents a history about the concept 'class').

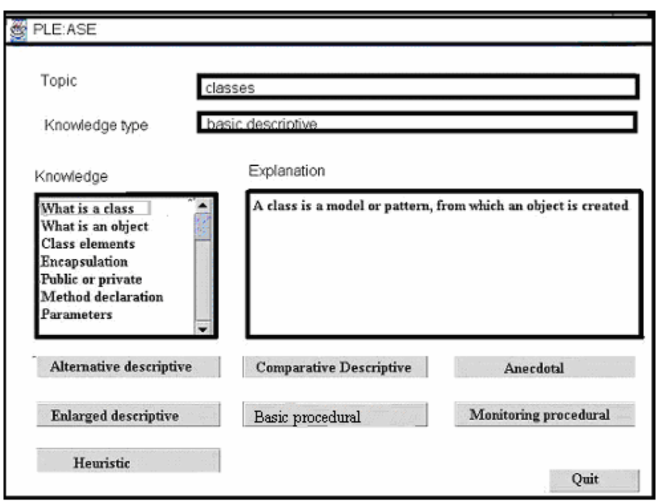

FIGURE 2
ENVIRONMENT

In this case, the selected subject is a first course of Object Oriented Programming, but the model could be applied to any other area of intellectual content because it is general, it is related to knowledge itself. For instance, if we consider Elementary Math, particularly the topic 'Progressions', a basic DK offered to the student could be the definition of an arithmetic progression, a basic PK related to it could be the process to calculate the sum of an arithmetic progression, an HK may be the suggestion of 'take into account the sum of 1 + 2 + 3 + ... because it is useful for calculations' and as an AK we could have the well known story of Gauss at school, when he was asked to calculate 1 + 2 + 3 + ... + 100 [27].

The expected use of the system starts from the student's recognition (or the perception by the system) of ignorance about some topic. Then, the existing knowledge in the environment about that topic is offered, labeled according to the kind of knowledge. This approach transfers to the student the responsibility of knowledge and ignorance management, thus encouraging self-teaching and boosting autonomous, independent work. Moreover, the student has the institutional memory available, wherein answers to frequent questions, knowledge about best practices and learned lessons may be found, and in which new elements may be included so individual skills can be integrated to the group or organization, enhancing its participation in the learning CP.

III. Experimentation and results

The environment hypothetically helps to:

? **Understand a problem**: given a problem situation, understand what it is;

? **Search for new ways to solve problems**: by identifying a problem situation, conceptualizing it, and advancing towards its solution; and

? **Apply already learned knowledge**: solving a given problem taking elements from previousy solved problems by applying analogies, inferences, deductions, etc.

The independent variable or treatment [28] in our experimentation is the usage of the environment by the student. The dependent variables that indicate if the treatment had some effect are: 1) grade of understanding of the problem; 2) number of ways found to solve a problem; and 3) grade of application of already learned knowledge.

Three student groups took part in the experiment, as shown in Table I.

TABLE I
GROUPS AND ACTIONS IN THE EXPERIMENT

GROUP	ACTION
I) Control	a) Took the standard course (with lectures and practice sessions)
II) Training	a) Took the standard course (with lectures and practice sessions) and b) received training (lectures) for problem solving and KM
III) Training and environment	a) Took the standard course (with lectures and practice sessions), plus b) received training (lectures) for problem solving and KM and c) used the environment

Students were randomly distributed among the three groups. Group sizes are shown in Tables II and III. As shown in Table I, Group I received the usual course. Group II received the same course plus theoretical material about KM and problem solving strategies. Each week, at least 15 minutes of a class were dedicated to these topics. Group III received the same course as Group II, plus the environment, which was available in class and in a laboratory manned with assistants and 25 computers from Monday to Friday, 7:30 am to 23:30 pm. Each student of Group III used the environment at least during 20 minutes of a class every week.

Two tests were given to each student in every group, both tests with three questions each. The first test was given at the beginning of the course, the second at its end. Both tests were graded using ordinal scales. In each test, one question was aimed to each expected result, namely a) *Understanding of a problem*; 2) *Ways to solve a problem*; and 3) *Application of knowledge)*. The questions in the first test were as follows (the second test was very similar):

Question 1) There is a list with all the buyers of lottery tickets. For each buyer, the ticket numbers and prizes won are registered. An alphabetic listing of all buyers who won more than one prize is needed: indicate all steps needed to perform this job with a program.

Question 2) You are working on a system development project and somebody suggests using Class X, which you do not know. In which ways could you find information about Class X?.

Question 3) A pet shop is defining a management information system. Please enumerate possible domain classes and relationships.

Elements or factors for assessing the answers to the *first* question were: 1) consider only winning numbers; 2) all buyers contacted; 3) each buyer is asked how many prizes were won; 4) registering all buyers with more than one prize won; 5) sorting the list alphabetically; and 6) displaying said list. For the *second* question, the factor considered was how many correct options were presented. Factors for assessing the answers to the *third* question were: 1) classes indicated; 2) enough attributes were recognized; 3) methods indicated; 4) aggregation relationship was used; 5) association relationship was used; and 6) inheritance relationship was used.

Each question was graded from 0 to 4 . The first and third questions were graded as follows: completely correct solution: 4 points; almost correct solution: 3 points (for 5 or 4 correct factors); incomplete solution: 2 points (includes 3 or 2 correct factors); wrong solution: 1 point (at most 1 correct factor); no answer: 0 point.

The second question was evaluated as follows: 3 or more feasible options or ideas: 4 points; 1 or 2 feasible options or ideas: 3 points; some feasible and non-feasible options or ideas, with a majority of feasible: 2 points; 4) majority of non-feasible options or ideas: 1 point; and 5) no answer: 0 point.

The samples were compared using Mann-Whitney and Kruskal-Wallis tests [28]. The experiment was performed twice, in 2002 and 2003. In 2002, at the beginning of the course, no significant differences were found between groups. At the end, significant differences (a = 0.05, 0.10) were detected in problem solving ways and application of knowledge between Group III and the other Groups. In 2003, there were no significant differences regarding 'understanding of problem' in both evaluations. Significant initial differences in the ability to search for ways to solve problems were found (Group III was the worst). At the end, no differences were found in relation to this topic. As to application of knowledge, no differences were initially found, but at the end, group III showed significant differences.

Also, the difference of marks was calculated for each student and problem. The results of the 2002 experiment are presented in Table II; results for 2003 are shown in Table III.

TABLE II
EXPERIMENTATION RESULTS: 2002

	QUESTION 1 UNDERSTANDING OF THE PROBLEM	QUESTION 2 WAYS TO SOLVE A PROBLEM	QUESTION 3 KNOWLEDGE APPLICATION
I - CONTROL GROUP (8 STUDENTS)			
IMPROVED	4 (50.00%)	2 (25.00%)	3 (37.50%)
STAYED EQUAL	2 (25.00%)	3 (37.50%)	3 (37.50%)
WORSENED	2 (25.00%)	3 (37.50%)	2 (25.00%)
II - TRAINING GROUP (19 STUDENTS)			
IMPROVED	4 (21.10%)	9 (47.40%)	3 (15.80%)
STAYED EQUAL	10 (52.60%)	5 (26.30%)	9 (47.40%)
WORSENED	5 (26.30%)	5 (26.30%)	7 (36.80%)
III - TRAINING PLUS ENVIRONMENT (21 STUDENTS)			
IMPROVED	6 (28.60%)	17 (81.00%)	8 (38.10%)
STAYED EQUAL	11 (52.40%)	2 (9.50%)	13 (61.90%)
WORSENED	4 (19.00%)	2 (9.50%)	0 (0.00%)

TABLE III
EXPERIMENTATION RESULTS: 2003

	QUESTION 1 UNDERSTANDING OF THE PROBLEM	QUESTION 2 WAYS TO SOLVE A PROBLEM	QUESTION 3 KNOWLEDGE APPLICATION
I - CONTROL GROUP (12 STUDENTS)			
IMPROVED	3 (25.00%)	3 (25.00%)	3 (25.00%)
STAYED EQUAL	4 (33.33%)	6 (50.00%)	5 (41.67%)
WORSENED	5 (41.67%)	3 (25.00%)	4 (33.33%)
II - TRAINING GROUP (18 STUDENTS)			
IMPROVED	4 (22.22%)	5 (27.77%)	2 (11.11%)
STAYED EQUAL	4 (22.22%)	10 (55.56%)	9 (50.00%)
WORSENED	10 (55.56%)	3 (16.67%)	7 (38.89%)
III - TRAINING AND ENVIRONMENT (21 STUDENTS)			
IMPROVED	9 (42.86%)	12 (57.14%)	13 (61.90%)
STAYED EQUAL	2 (9.52%)	8 (38.09%)	6 (28.57%)
WORSENED	10 (47.62%)	1 (4.77%)	2 (9.53%)

In both cases (2002 and 2003), data were also analyzed by grouping low values (0 and 1) and high values (3 and 4). Through those analyses (detailed and grouped), and the results of the Mann-Whitney and Kruskal-Wallis tests [28] we may infer that:

? No statiscally significant improvement was detected in problem understanding in Groups II and III. An interpretation of this unexpected result could be that the necessary activities for problem comprehension (for instance, problem understanding or detection of important elements) are not related to or fostered by the different knowledge types and KM.
? The students of Group III showed a remarkable improvement in the number of ways devised to solve a problem. They were able to find, apply and explain more ways, with disregard of what the initial differences were.
? Most of Group III students improved their ability to apply knowledge and few get worse.

CONCLUSION AND FUTURE WORK

In this paper, a relationship is established between KM, knowledge codification, CP and LEs. The LE model presented is based on KM and foments CP because it integrates information and allows its renovation. It explores codified knowledge and manages it actively. It may be applied to other areas of knowledge of different intellectual content and is adaptable to different strategies according to behavior and style of student learning.

We developed an environment applying the model. Through experimentation, it was found that the students who used the environment showed a remarkable improvement in the number of ways for solving a problem: they could identify, apply and explain more ways. Also, those students improved their ability to transfer knowledge learned to new situations.

In future work, an automatic and intelligent tutorship based on agents should be included as well as elements that allow cooperative work and direct interaction between students and/or teachers, in order to better take into account the social aspects of learning.

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