



Knowledge Management Integrated with e-learning in Open Innovation

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Abstract

This paper presents a framework aiming to support an «innovation chain» in an Open Innovation (OI) perspective. In order to transfer research results from producers to users, it is necessary to develop a Knowledge Management System supporting formalization, packaging and characterization to be able to select, understand and collect research results and/or innovations deriving from them. Suitable skills are required to transfer and collect innovation. Since in OI the knowledge producer and final users are by definition geographically distant, the required specialist skills have to be acquired through an e-learning system. This system must offer Learning Objects that can be combined within a course that also takes into account the user's past experiences. This work proposes an approach based on the integration of these two systems, and presents PROMETHEUS, a tool supporting this approach. The results of preliminary experimentation highlighted the strengths and weaknesses of the approach. They will be used to plan further experimentation and initiatives serving to facilitate the transfer of research results from state of the art to state of practice.

1. Introduction

The ever increasing competitive stress to which firms are subjected has made product and process innovation a crucial issue. In turn, this requires ever shorter innovation execution times and a greater cooperation between the adopted innovation and training in its use (figure 1).

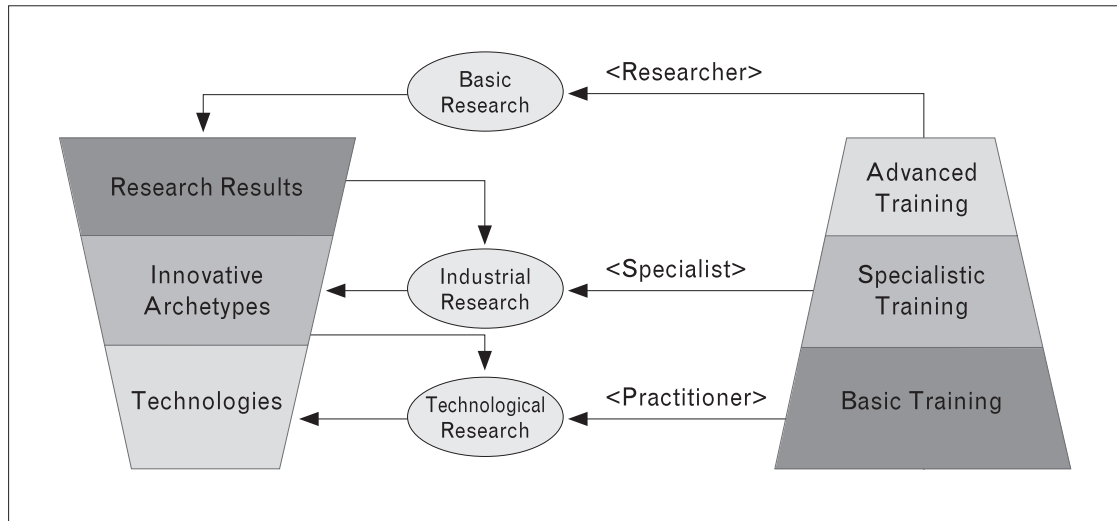


Figure 1 Innovation and training cycle.

In the innovation cycle the results generated by basic research are suitably selected, integrated and transformed into innovative archetypes. The latter constitutes an operative body of knowledge that is applicable in the productive processes, together with the demonstration prototypes made to facilitate the use of the new knowledge during operations. Once the archetype has been refined and shown to be fully efficacious, it is transformed into technology, i.e. a set of practices derived from the body of knowledge, and of tools derived from the demonstration prototypes. The technologies are introduced in the production process, ending the innovation cycle.

Like the innovation cycle, the basic training process must provide for acquisition of the skills needed to apply the practices and tools in the productive processes, as well as specialist skills enabling analysis of when, how and where the research results can best be used to transform them into innovative practices. Advanced training is needed to produce resources able to create new knowledge through basic research. The training process must be able to keep pace with the continuous changes of the innovation cycle.

This growing need to carry out rapid innovation processes, as well as the high cost of research, have given rise to so-called Open Innovation processes (Chesbrough, 2003; Ardimento, Cimitile and Visaggio, 2003; O'Reilly and Tushman,

2004; Edquist, 1997). If a company or research institution is unable to use the results of research straight away, they are made available for use by other companies or institutions. The institution supplying the results can, if it so desires, sell them and reinvest the returns in further research. The advantage for the institution purchasing the results is that it can bypass the research risks: at an agreed price it acquires research results serving to improve its business processes.

However, the notorious dichotomy between researchers and practitioners poses a barrier to the spread of Open Innovation (Reifer, 2003; Glass, 2005). The former complain that their research results build up but are not used by industry. The latter lament the strong need for innovation and lack of support by research results (Xiangyang, Linpeng and Dong, 2004; Joshi, Sarker and Sarker, 2005). Another barrier to Open Innovation is the need for adequate training in the use of the knowledge contained in research results. In fact, resources may undergo general training but to apply a specific research result, an archetype or a technology, specific education and training will be needed.

The approach presented in this work aims to mitigate these two problems by managing the knowledge/experience package with the relative information tool. The Authors use the term knowledge package to refer to an organized set of: knowledge content, teaching units on the use of the demonstration prototypes or tools and all other information that may strengthen the package's ability to achieve the proposed goal. The knowledge package must be usable independently of its author or authors and for this purpose, the content must have a particular structure: distance education and training must be available through an e-learning system. In short, the proposed knowledge package contains knowledge content integrated with an e-learning function.

The rest of the paper is structured as follows: related works and research activities are discussed in section 2; section 3 presents the proposed approach, focusing particularly on the relative Knowledge package, Metadata and Life Cycle; section 4 introduces the Knowledge Base set up by the SERLAB research team and outlines some preliminary experimental results serving to validate and facilitate the process, and describing a test sample. Finally, in the conclusions some observations are made about the preliminary results obtained, and possible future research pathways are identified.

2. Related works

The problem of knowledge packaging for better usage is being studied by many research centers (Jedlitschka and Pfahl, 2003; Malone, Crowston and Herman, 2003) and companies (Jedlitschka and Pfahl, 2003; Schneider and Schwinn, 2001). The knowledge bases produced sometimes have a semantically limited scope. This is the case of the Daimler-Benz base (Malone, Crowston and Her-

man, 2003; Schneider and Schwinn, 2001), that collects lessons learned or mathematical prediction models or results of controlled experiments in the automobile domain only. In other cases the scope is wider but the knowledge is too general and therefore not very usable. This applies to the MIT knowledge base (Malone, Crowston and Herman, 2003), that describes business processes but only at one or two levels of abstraction. There are probably other knowledge bases that cover wider fields with greater operative detail (Schneider and Schwinn, 2001) but we do not know much about them because they are private knowledge bases. Another solution being examined by the research community is ontologies (Tao, Millard, Woukeu and Davis, 2005; Huang, O’Dea and Mille, 2003; Chen and Wu, 2003), but these currently lack tools for creation and management (Klein 2001). Much attention is being focused on these issues but the available experimental evidence is not yet sufficient for large-scale use.

Our approach focuses on a knowledge base whose contents make it easier to achieve knowledge transfer among research centers; between research centers and production processes; among production processes. The knowledge base must be public to allow one or more interested communities to develop around it and exchange knowledge. In particular, it must be possible for small and medium sized businesses (SMB) to become members of these communities. In fact, we believe that only membership of these special interest communities can allow SMB to adopt Open Innovation and reap the benefits.

The knowledge base must cooperate with an e-learning system. Cooperation between these two tools aims to achieve knowledge transfer from the senders to the addressees of the knowledge. Thus, our approach intends to use e-learning in cooperation with knowledge bases, as a means of linking conceptual knowledge to the operative knowledge needed to transfer the content of the knowledge package to practitioners, specialists or other researchers.

3. The Proposed Approach

3.1 Knowledge/Experience packages

In the proposed approach, the knowledge/experience package must include all the elements shown in figure 2. A user can access one of the package components and then navigate along all the components of the same package according to her/his training or education needs. Search inside the package starting from any of its components is facilitated by the component’s Metadata.

It can be seen in the figure that the Knowledge Content component (KC) is the central one. It contains the knowledge package expressed in text form, with figures, graphs, formulas and whatever else may help to understand the content. The content is organized as a tree. Starting from the root (level 0) descent to the lower levels (level 1, level 2...) is through pointers (figure 3). The higher the level

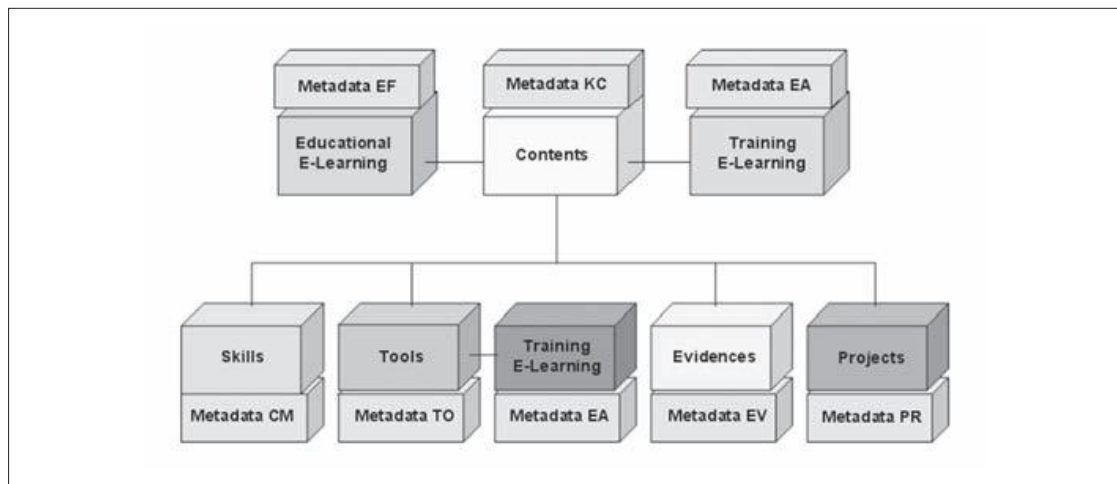


Figure 2 Diagram of a Knowledge/Experience package.

of a node the lower the abstraction of the content, which focuses more and more on operative elements. The root and each intermediate node contain the reasoned index of the underlying components (figure 3). The content consists of the following: research results for reference, analysis of how far the results on which the innovation should be built can be integrated into the system; analysis of the methods for transferring them into the business processes; details on the indicators listed in the metadata of the KC inherent to the specific package, analyzing and generalizing the experimental data evinced from the evidence and associated projects; analysis of the results of any applications of the package in one or more projects, demonstrating the success of the application or any improvements required, made or in course; details on how to acquire the package.

In line with Open Innovation, the research results integrated by a package may be contained within the same knowledge base or derive from other knowledge bases or other laboratories. If the knowledge package being read uses knowledge packages located in the same experience base, the relations will be explicitly highlighted.

When a knowledge of some concepts is a prerequisite for understanding the content of a node, the package points to an educational e-learning course (EF). Instead, if use of a demonstrational prototype is required to become operative, the same package will point to a training e-learning course (EA) (figure 4). As stated above, the use of these courses is flexible, to meet individual user's needs.

To integrate the knowledge package with the skills, KC refers to a list of resources possessing the necessary knowledge, collected in the Skills Component (CM).

When a package also has support tools, rather than merely demonstration prototypes, KC links the user to the available tool. For the sake of clarity, we point out that this is the case when the knowledge package has become an industrial practice,


Pacchetto: Multiview Framework in GQM				
Attributi	Contenuti	Allegati	Relazioni	Contatti
				
Multiview Framework in GQM				
<p>The <u>Goal Question Metrics (GQM) paradigm</u> is a set of guidelines for defining goal oriented quality or metric modes and flexible with respect to: goal contents, object to monitor, aim of measurement, perspective and context to measure. Due to flexibility, in real contexts quality models produced following this paradigm have many goals and measures, i.e. they tend to be of large dimensions. Such high dimension most likely increases interrelations between question of a goal and between goals of the same quality model. The number of interrelations expresses the model's complexity. So, the dimensions of a GQM also lead to complexity. In order to improve their comprehension and management specific instruments that collect experience and formalize quality models with the same guidelines of GQM can be used. A systematic approach for defining, evaluating and managing a large quality model is the <u>Multiview Framework</u>. In order to improve readability and explicitly trace monitoring and GQM/QIP continuous improvement, <u>Abstraction Sheets</u> are used. Finally, a quality model must be operational, i.e. it must express the interpretation of possible values that the metrics it contains can assume. The large dimensions of a GQM and the consequent complexity make expression of interpretation also complex. To mitigate such issues, <u>Decision Tables</u> are used. The set of these innovative practices, integrated and coordinated innovate the traditional GQM paradigm. These practices are supported by the following demonstration prototypes: <u>GQM Editor</u> and <u>Prologa</u>.</p>				

Figure 3 Sample of content of a Knowledge/Experience package.

Pacchetto: Multiview Framework in GQM				
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Multiview Framework				
<p><u>Multiview Framework Model</u> is a GQM-based approach that provides support in designing a structured measurement plan in order to overcome the comprehension problem of a large industrial measurement plan. The approach generates the following values for stakeholders: a) provides some guidelines for designing a GQM so that each time point involves a limited number of goals to measure and interpret. This guarantees higher efficacy, for the designer, during the design phase of a goal, and a simplicity and ease in interpreting results, for the analysis; b) provides guidelines for reducing the model's complexity. This ensures a higher efficacy during goal design and effectiveness during the control phase. Also it allows a continuous improvement of the model; c) provides guidelines for controlling and improving interpretation allowing higher effectiveness and efficacy d) improves comprehensibility of interpretation, questions and goals. What is stated in a), b), and c) has been validated by applying the proposed approach to an Industrial Project recently carried out without using the Multiview Framework approach. In particular, the approach has been experimented with an <u>Analysis On Legacy Quality System</u> that has sensibly reduced the complexity of the Quality System by applying the approach to the legacy and generating a new quality system. For what concerns improvement of comprehensibility, a <u>Controlled Experiment of Interpretation Comprehension</u> has been carried out. In this case the legacy quality system was compared to an equivalent one designed with the Multiview Framework approach. In this case correctness, efficacy and effectiveness of interpretation are improved.</p>				

Figure 4 Sample of 2nd level content of a Knowledge/Experience package.

so that the demonstration prototypes included in the archetype they derived from have become industrial tools. The tools are collected in the Tools Component (TO). Each tool available is associated to an educational course, again of a flexible nature, in the use of the correlated training e-learning course (EA).

A knowledge package is generally based on conjectures, hypotheses and principles. As they mature, their contents must all become principle-based. The transformation of a statement from conjecture through hypothesis to principle must be based on experimentation showing evidence of its validity. The experimentation, details of its execution and relative results, are collected in the Evidence component (EV), duly pointed to by the knowledge package.

Finally, a mature knowledge package is used in one or more projects, by one or more firms. At this stage the details describing the project and all the measurements made during its execution that express the efficacy of use of the package are collected in the Projects component (PR) associated with the package.

3.2 Metadata

As shown in figure 2, each component in the knowledge package has its own metadata structure. For all the components, these allow rapid selection of the relative elements in the knowledge base. The focus in this work is on the metadata in the KC. In fact, these have been defined during research conducted by the authors and by other authors. To facilitate the research, we used a set of selection classifiers and a set of descriptors summarizing the contents. The classifiers include: the key words and the problems the package is intended to solve. The summary descriptors include: a brief summary of the content and a history of the essential events occurring during the life cycle of the package, giving the reader an idea of how it has been applied, improved, and how mature it is. The history may also include information telling the reader that the content of all or some parts of the package are currently undergoing improvements.

The package also provides the following indicators: skills required to acquire it, prerequisite conditions for correct working of the package, acquisition plans describing how to acquire the package and estimating the resources required for each activity. To assess the benefits of acquisition, they contain a list of: the economic impact generated by application of the package; the impact on the value chain, describing the impact acquisition would have on the value of all the processes in the production cycle; the value for the stakeholders in the firm that might be interested in acquiring the innovation. There are also indicators estimating the costs and risks. Thus, all these indicators allow a firm to answer the following questions: what specific changes need to be made? What would the benefits of these changes be? What costs and risks would be involved? How can successful acquisition be measured?

3.3 Life cycle

The knowledge package is inserted by its administrator, or by an expert belonging to the special interest community developing around the knowledge base, having the requisite knowledge and skills. Initially, a knowledge package may be only a research result, in which case it will only have descriptive parameters in the metadata and may lack any other linked information apart from the name/s of the expert resource/s listed in the Skills component. Instead, if it is an innovation it will have an archetype which must include both the knowledge derived from the results and demonstration prototypes. The metadata will be validated as above, and education and training e-learning courses may also be included to learn how to use the prototypes.

Experimentation of the archetypes present in KC may have been made, and at its conclusion, the description of the experiment, the metrics and the results may be inserted in EV. KC will also contain the indicators of the metadata that can record the results of the experiment, a history of the new event and, in the content, comments and a consideration of the significance of the new indicators, as well as a description of analysis of the results of the experiment and their relative values in terms of the indicators. If the experiment yielded any negative results, suggestions for improvement of the package may be included. These are recorded in detail in KC and summarized in the history.

In general, the knowledge base administrator or perhaps a stakeholder may carry out industrialization of an archetype considered to have been adequately validated. In this phase, the acquisition plans are formalized, validated by the summarized metadata and the detailed descriptors in the KC. Demonstration prototypes are thus transformed into industrial tools, stored in TO and linked to the knowledge package in KC. Also in this phase, if they are not already present, EA and EF e-learning courses must be inserted. The history of the package must be updated.

Application of the package is by use in a project. PR records a description of the project, the model and the metrics plan, as well as the measurements made. Statistical analysis is made of the latter, and a brief summary of the results is included. The corresponding KC will validate the indicators of the metadata serving to record the results of the project, the new event will be recorded in the history and comments will be added in the contents, as well as the significance of the new indicators, a description of the analysis of the project results and their connection with the values inserted in the indicators. Again, if the project has yielded any negative results, improvements may be hypothesized, recorded in detail in KC and summarized in the history.

The package is subject to continual improvements as a result of the initiatives suggested by the experiments, of use or of an autonomous decision taken by the

administrator if new knowledge appears in literature or internal/acquired research yields new results.

4. Experimentation

The demonstration prototype of the knowledge base, named PROMETHEUS (Practices pROcess and Methods Evolution Through Experience Unfolded Systematically), has been created using J2EE technology. The e-learning platform is an open source suited to our needs.

We carried out a first investigation by transforming some of the results found in literature into knowledge/experience packages. Our first results are shown in table 1, demonstrating that 56% of the papers analyzed had a relation m-1 with the packages (6 papers in package 1 and 2 papers in package 4). This means that the contents of a knowledge package are disseminated in literature. Moreover, the effort for reading and transforming the contents of the papers into a package were relatively high. In short, the literature is not a good tool for acquiring research results to be integrated in business processes.

Table 1
TRANSFORMING THE ARTICLES INTO KNOWLEDGE PACKAGES.

<i>ID. Publication</i>	<i>Reading time in minutes</i>	<i>Transformation time</i>	<i>ID. Package</i>
[17]	165	185	1
[23]	130	225	1
[24]	154	125	2
[25]	254	130	3
[26]	140	170	4
[27]	145	160	4
[28]	195	215	1
[29]	125	225	5
[30]	160	265	6
[31]	150	200	1
[32]	140	290	1
[33]	180	265	7
[34]	130	240	1
[35]	165	205	8

Table 2 shows the validated indicators for all the packages extracted from the articles examined above.

Table 2
INDICATORS EXTRACTED FROM THE EXAMINED ARTICLES

<i>Indicators</i>	Packages							
	1	2	3	4	5	6	7	8
History	-	-	-	-	-	-	-	-
Prerequisites	-	-	-	-	-	-	-	-
Economic Impact	-	-	-	-	-	-	-	-
Impact on the Processes	x	-	x	x	x	x	-	-
Impact on the Products	x	x	x	x	-	-	x	-
Value for the stakeholders	-	-	-	-	-	-	-	-
Risks of Application	-	-	-	-	-	-	-	-
Planning	-	-	-	-	-	-	-	-
Evidence	x	-	x	x	-	x	-	-

Table 2 shows that much of the information serving to foster reuse of the knowledge package is not present in the papers examined. Thus, the available knowledge is incomplete, likely due to a disparity of interests between researchers and practitioners. We then carried out a further experiment: we inserted a Quality Management package as an archetype, based on the Goal Question Metrics paradigm, with the following innovative practices: structuring the interpretation of the metrics; inserting Abstraction Sheets for validating quality models and representing them, improving their readability, together with an approach to quality system structuring named Multiview Framework, and Decision Tables to make interpretation operative. The package also contains the following demonstration prototypes: GQM-Editor; Prologa. The components PK, EV and CM in the package were adequately populated. It also contains training and education courses on the PK contents and demonstration prototypes, for a total of 54 Learning Objects. The package does not include validated indicators concerning metadata.

The package was made available to university students following the course on Assessment Models in the third year of the Degree Course in Information Science. They were asked to acquire a knowledge of the innovations and their use. The exercises set at the examination showed that 83% of the students had applied the innovations satisfactorily, solving the problems set. Of these students, 95% had used all the innovations correctly. These data show that the knowledge package was correctly learned in the classroom and with the e-learning function contained in the package. In this case, the absence of indicators did not affect the results because the students did not need the business case, but had to acquire the innovation as a part of their study plan.

5. Conclusions

Our work addresses innovation transfer inside business processes. Starting from the observation that the innovation cycle is affected by limitations as regards collection and divulgation of the results of research and the resulting archetypes, it was found that one of the causes of this is the extreme dissemination of research results in different papers, books and other publicly available resources. We propose a Knowledge Management System that collects knowledge packages featuring localized research results, linked to the resulting archetypes and technologies they generate. The system includes methods for structuring the contents, guidelines for linking the primary knowledge content to other data assisting acquisition and use of the innovation. Finally, the system makes use of descriptors and indicators that help to trace the knowledge package/s that can solve the potential user's problems and to convince her/him of the efficacy of use of the candidate package/s.

The educational and business sectors need to be linked to the information cycle. For this reason, the system includes an e-learning System teaching knowledge of the packages and training the user in the use of the demonstration prototypes or tools supporting an innovation. We propose PROMETHEUS, a demonstration platform that integrates a Knowledge Management System and a Learning System, allowing navigation among all the components. Thanks to this platform, we experimented the proposed approach, and found that:

- the system allows consolidation of a knowledge package disseminated in many different articles;
- quite a lot of man time is needed to transform the knowledge expressed in articles and books into a knowledge package;
- for many packages, it was not possible to validate all the metadata shown by previous experiments to be useful to convince business administrators to acquire the innovation;
- the knowledge base was able to transfer the innovation to students carrying out a study project focusing on real industrial case studies.

Much experimentation has still to be done. In particular, we must pass on from classroom experimentation to in-field experimentation in a real business. The efficacy of the structure of the knowledge/experience package needs to be validated, as well as the approach's ability to achieve continuous improvement of the knowledge package contents and relative e-learning courses.

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