Proceedings of the 19th CIRP Design Conference – Competitive Design, Cranfield University, 30-31 March 2009, pp17

How to Answer to the Challenges of Competencies Management in Collaborative Product Design?

B. ROSE[1], V. ROBIN[2] and S. SPERANDIO[2]
[1]LGECO laboratory, ULP/INSA Strasbourg, 24 boulevard de la Victoire
67084 Strasbourg Cedex, France
[2] IMS Laboratory – LAPS department, UMR 5131 CNRS, University of Bordeaux,
351 cours de la Libération,
33405 Talence Cedex, France.
bertrand.rose@insa-strasbourg.fr, vincent.robin@ims-bordeaux.fr, severine.sperandio@ims-bordeaux.fr

Abstract
Collaboration is an essential factor of the design activities performance. This collaboration occurs between actors suited with varied expertises, coming from various trades and thus building a real network around the design project. It is advisable to manage with effectiveness the follow-up and the capitalization of information exchanged within this network. With the aim of increasing the performance of the design activity, the set up of competence management tools within the design teams is today necessary. However, these competencies management within a framework of collaborative design must answer various challenges. This article presents various proposals to answer them.

Keywords:
Collaborative Design, Dynamic Competencies Management, Design Process Management.

1 INTRODUCTION

Human resources directly influence efficiency of the relationships in the companies and of the decision-making in product design. They play a crucial role in this process [1] by making evolve the object on which they are working by their successive choices. They also influence the resolution of the problems by using their knowledge and their expertises. In design, evolution of the product and resolution of problems are closely influenced by the management of human resources in the organization. Garel *et al.* [2] highlight the problem of the human resources policies adaptation: how to adapt the policies and the human resources management tools which are historically developed for the functional organizations? Authors also point out the fact that policies are focused on the formal knowledge and not on the capacity to diffuse them and to capitalize them. Thus, even if the technical skill remains an element of choice in the assignment of the actors, it is not the single parameter to be taken into account any more. Within the framework of the collaborative design in which human resources evolve, the creation of collective competencies supposes a good interaction and a good collaboration between the various actors of the workgroups. These competencies are certainly based on individual expertises and competencies in management but also strongly call upon actors' knowledge-being [3]. In parallel, the use of "collective knowledge" and in particular of popularization knowledge [4] seems to be necessary to mobilize and to reveal actor's knowledge but also knowledge which is capitalized in actor's networks. Popularization knowledge is the basis of "knowledge to collaborate" and "collective competencies".

In this paper, we describe the challenges and the needs relating to the development of competencies management tools to support collaborative product design. In a second time, we present solutions to answer these challenges, by proposing a "network" approach to consider the evolutions of the context in which the design activities proceed. We also present specific matrix to chart competencies. Finally, we propose prototype of software solutions to answer these challenges.

2 CHALLENGES AND NEEDS FOR COMPETENCIES MANAGEMENT

2.1 Study of the functionalities of the existing tools supporting competencies management

Even if many studies on Knowledge Management (KM) exist, the tools to support KM are always in development. Moreover, they often lock up the organizations in a static structure, circumscribed by the system. They are not flexible and not adaptable to new contexts of work or new organisational orientations. Lindgren classifies the researches relating to the development of competencies management tools according to 3 currents [5]:

- . The CSCW approach. Its goal is to facilitate the co-ordination of the workgroups and the co-operation between the different actors. Effective collaboration in a stable and specific context are not considered,
- The Information System approach. Its aim is to offer users and researchers methodological guides and toolkit to implement a competencies management tool adapted to an organization [6],
- Contributions from the Organisational Theory in Knowledge Management which recommend methodologies to develop KM systems and competencies management systems for KM driven organizations.

We locate our research in this last current, proposing software applications supports to these contributions. These applications must be integrated, as well as the other tools for the design, in the Information System. They must also consider an essential parameter of the competencies management: their dynamic evolution.

2.2 A real need to consider the dynamic components of the organization

The competencies management tools have to provide information about the actors' personal expertises in an organisational context but they have also to be to propose a more global vision of collective competencies. They have to promote the effective division of this knowledge and collaborative competencies. This concept is significant in the context of the design in which the search for performances is permanent and the innovation is subjacent with each design activity. Such a context obliges a perpetual dynamic evolution of the organization. The taking into account of this evolution in term of adaptability to the organisational changes reinforces the concept of team and community in the design projects. Our work proposes to provide a methodological guide and tools to consider the dynamic of the organization according to the 4 challenges stated by Stenmarck [7]:

- The challenge of the competencies cartography. It consists to index and make available various existing competencies in a service or in a group of actors.
- The challenge of the competencies evolution. It consists in proposing an updated cartography of these competencies and the tools and the methods able to anticipate these evolutions in the organization.
- The challenge of the collection of the input data implying that a competencies management system must be enriched by the individuals whom it indexes. In our case, the decision-makers must feel the interest of such a system to provide him adequate and useful information.
- The challenge of data isolation that concerns the provision of key information which is a preoccupation with confidentiality.

We base our proposals on the design environment concept [8] and Robin's researches on the evaluation of the performance of design systems [9]. In the following section, we analyze the contribution of the cartography of the existing networks within the projects. Then we propose the use of competencies matrix within a framework to consider the organization evolutions to support the design activities.

3 A NETWORK OF DESIGNERS

3.1 A cartography of the networks to design project management

According to the Håkansson *et al.*'s model of network in the industrial marketing field [10], Nowak *et al.* [11] proposed a design process model. They suggested that the design environment can be seen as a "network" gathering the elements "actor", "activities" and "resources". Such a model allows us to make a distinction between a network of actors, a network of activities carried out between these actors and a network of resources used by these actors [12]. The vision "actor-activity-resources" of the networks was first developed to explain the interactions between inter-connected networks in the context of transactions in industrial marketing. This model is adapted in the context of the product design to chart and specify the various existing relationships within the design teams [13]. The visualization of these links contributes to the evaluation of the intensity of the various relationships. Figure 1 illustrates the visualization of relationships from a real case study. It concerns our industrial partner during the design process of a sheet stator of an electric motor. The study of this network appeared interesting since it allows us to identify the actors which have collaborations within the group. It highlights actors which are able to use their expertise to inform their colleagues and to make evolve competencies of their interlocutors.

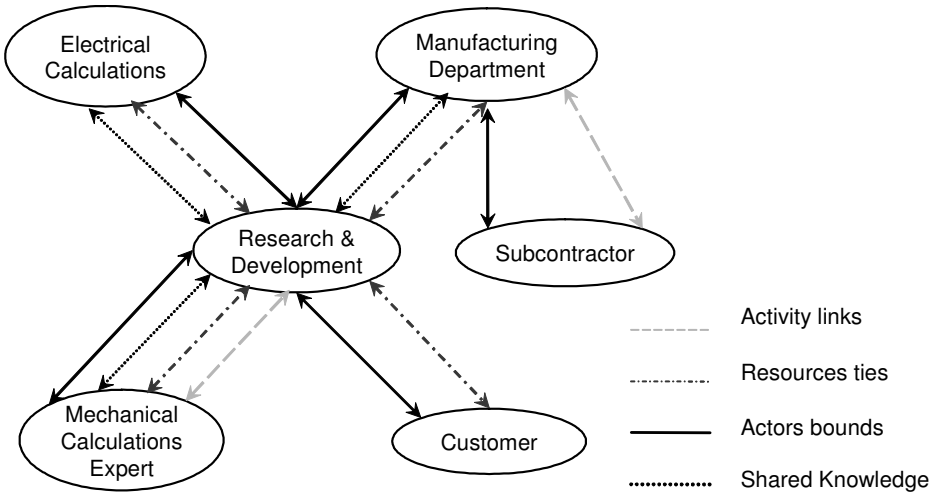

Figure 1: Cartography of the various networks established when designing a sheet stator of an electric motor

This visualization partially answers to the challenge of competencies cartography. It highlights in which field and how the actors collaborate within the current organization. It also brings a response to the challenge of the competencies evolution within the organization, in particular by the study of the knowledge exchanged between the actors in the collaborative networks. It gives an indication of the evolution of each actor's competencies. A quantitative analysis of the various existing links between the actors permits to generate performance indicators concerning various aspects of the collaboration. In the case of repetitive studies, valuation of these performance indicators regarding to specific situations could be used to support decision-makers in the choice of actors in similar situations [12], [14].

However, the study and the cartography of the various existing networks within the design team don't answer to the last 2 challenges. For instance, the project manager

has difficulties to recover pertinent information and to establish the reality of these networks. To go far from the simple cartography of the network we propose to complete our approach with competencies cartography. It permits to think about preliminary concepts to develop an effective KM tool to help design projects managers.

4 PROPOSITIONS FOR A COMPETENCIES CARTOGRAPHY IN COLLABORATIVE DESIGN

In the collaborative design context, the actor's qualities have to be considered to constitute efficient design teams [15]. The identification and the selection of the actors must be done with pragmatic tools. In our case, we chose to use competencies matrix to help decision-makers. Such a tool allows a company to identify and capitalize information relating to actors' competencies on given problems. We present in this section the various policies to develop the competencies matrix.

4.1 Using of competencies matrix

Two types of competencies matrix permit to specify and to make appear the various actors' competencies in a company, in a project or in a group within an organization:

- The matrix from a "trade" viewpoint,
- The matrix from a "produced" viewpoint.

Concerning the design activity, the competencies matrix from a "trade" viewpoint is based on existing documents of the company describing the activities of the various design actors according to their trade. It is also possible to have a classification according to the actors' function within the hierarchy of the studied service. The activities are categorized in four levels: functional objectives related to the responsibilities, intermediate objectives describing the missions associated with the tasks, actions and finally the software which is part of the actors' environment. For each activity, a level of control of described competencies is associated to each actor. This solution allows the dynamic competencies management by the intermediary of the parameter "level of expertise" separated in 3 criteria:

- The "necessary" level of expertise that is the minimal one required by the activity to ensure the good course of the process.
- The "specific" level of expertise corresponds to the difficulties awaited for given design activities. This level can be supplemented according to the actors' empirical experiment at the beginning of project and/or can be based on documents estimating the difficulty of a project on the basis of preset criterion. It permits to identify "a priori" the actors most suited to the resolution of particular problems.
- The "reached" level of expertise is supplemented at the end of the project, for each activity, during the end of project meeting. The examination of the divergences between the levels expected and those really reached can then be used as performance indicator to the evaluation of the formed group.

Concerning the competencies classification from a "produced" viewpoint (Figure 2), the nomenclature trade is broken up in the form of macroscopic or microscopic sets that represent different the levels of expertises:

- The microscopic level concerns an actor's level of expertise on a specific product as defined by Rakoto *et al.* [16]: the expert ensures his expertise near his internal and external customers. He capitalizes and makes share his expertise, and instigates knowledge of the field where he is recognized as a reference.
- The macroscopic level represents competencies according to the traditional triptych: "*knowledge, know-how and knowledge-to be"* to each actor intervening during the product design process.

When the design process is relatively well defined, structured and controlled, this approach offers a great visibility on the products designed and permits to identify the most qualified resource to achieve a task on a specific product. As proposed Hadj Hamou and Caillaud [15] this visibility can moreover be increased by adding a level of co-operation necessary for the various speakers within the design process.

Figure 2 presents an example of competencies matrix with a "produced" viewpoint for a team in of charged the design of asynchronous motors. Here, the microscopic level that emphasizes the actors' expertise is developed according to 4 levels. Each level is composed with prerogatives concerning:

- knowledge to achieve the task,
- achievement of the activity on which the actor is affected,
- the actor's autonomy of work,
- the quality of the analysis of the results

Such a structuring allows making go up information concerning the macroscopic level of actor's competence; with a flat concerning knowledge-being which is not an easily quantifiable concept.

The use of this kind of matrix helps management of collaborative design process by identifying the actors and their positioning on a given problem. Matrixes are tools for dissemination of the competencies management policy within a design project and design department. But without breaking the challenge of insulation of information (these data are not of confidential nature and remain generally diffused within the project). Matrixes also answer the challenge of collection of information previously stated since actors see the benefit of such an action. Indeed, within the framework of collaboration on a given activity, in addition to the interpersonal conflicts which can always exist within a team, this visualization of each actor's levels could be beneficial. Actors will be able to see the potential advantages by increasing their own competencies. This measurement potentially enables them to fill their differences. This ambition requires a financial profit-sharing on the overall policy of the company to increase the decision-makers' interest to post their qualification level objectively. Even if it can seem utopian, this position winner/winner can nevertheless improve total synergy of the design teams. It is advisable not to fall into a version perverted from the use of such matrix which would aim at selecting the best elements in the various categories and to be detached from services. Moreover, one major disadvantage of these competencies matrixes is that they are a static vision of the situation of the company, a project or a group of actors within a sub-project.

Competences matrix: Asynchronous motor N3						
Product		*Rotor*			*Carcass*	*Stator*
Sub-product		*Magnetic parts*	*Ventilation*	*Main shaft*		
Title	***Names***					
Project Manager	**P.A.C**					
Engineer	**D.M**					
	V.L					
	J.B.D					
Contractor	**Ph. A.**					
	M.O					

	Level 1	***Level 2***	***Level 3***	***Level 4***
Knowledge	Possess all the basis knowledge for the job	Ability to accomplish all the tasks of the job	Ability to accomplish all the tasks of the job	Ability to accomplish all the tasks of the job
			Ability to explain all the tasks of the job	Ability to explain all the tasks of the job
				Ability to be a trainer
Activity	Apply standards	Apply operative modes	Apply operative modes	Apply operative modes
		Ability to select and apply the appropriate standard	Ability to select and apply the appropriate standard	Ability to select and apply the appropriate standard
				Create new standards
			Create new standards	Ability to realise unusual operations
Autonomy	Work with a tutor	Work alone by respecting operative modes	Work alone by respecting operative modes	Work alone by respecting operative modes
			Make propositions of improvement actions	Make propositions and participate to improvement actions
Quality	Control his own work with a tutor	Control his own work alone	Control his own work alone	Control his own work alone
			Understand the results and make corrective actions with a tutor	Understand the results and make corrective actions alone
A level is achieve when all the criterion of this level are achieve				

Figure 2: Competencies matrix with vision " produced " and captions notation

4.2 Prototypes of software to support human resources management

During the IPPOP project [17] we developed the PEGASE application allowing the integration of the results obtained in the competencies matrixes. Objective was to use it to manage design project. Initially an administrator connects to database of PEGASE by means of a protected connection. According to the competencies matrices previously defined, he identifies the elements to be taken into account in the database and creates it. When competencies are implemented, he assigns to each actor his own competencies. This data is then accessible to the project manager via various tables and diagrams on a specific Graphical User Interface (GUI) (Figure 3). Project manager will be able to exploit them during the course of the project to assign the resources and to create teams. This application answers the challenge of setting to data layout, while ensuring their confidentiality and their timelessness and making sure their capitalization and their use compared to the other projects of the company. This software capitalizes a static vision of actors' competencies and is not able to give precision about the possible actors' evolution yet.

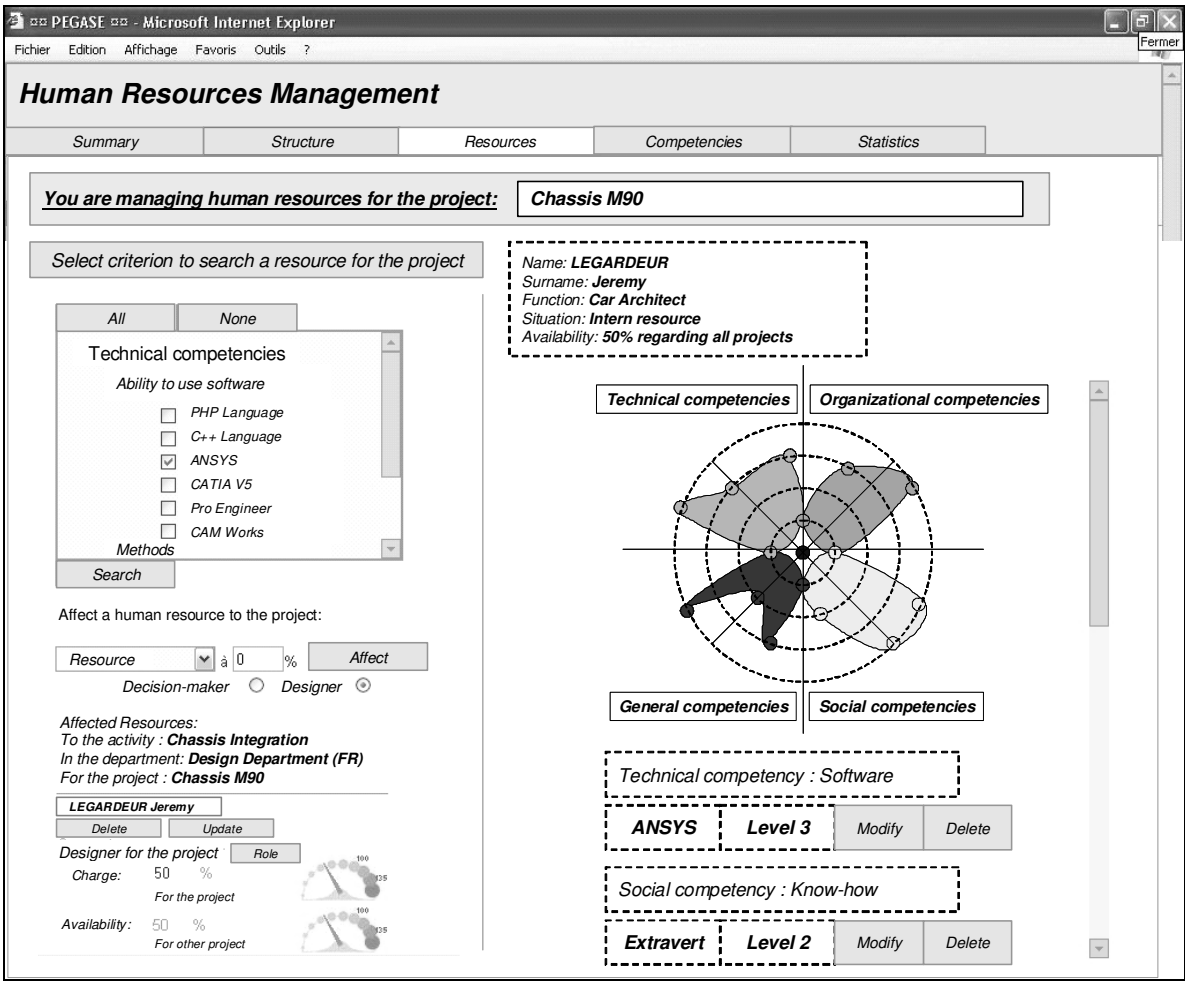

Figure 3: Graphical User Interface for the choice and the allocation of a resource on a project in PEGASE application

To complete this approach, Rose [18] was interested in conflicts management in collaborative product design. This situation is one of the most constrained cases of collaboration [19]. In order to instrument the conflicts management, CO²MED – a software application – (COllaborative COnflict Management in Engineering Design) was developed. It is based on a reference frame improving the effectiveness and preserving the memory of the resolution of the technical conflicts. This resolution process is integrated in an engineering process and has characteristics which can be parameterized and indicators that permit to judge its effectiveness. These indicators (metrics) give information compared to the actors' implications in the previous conflicts according to given expertises fields (figure 4).

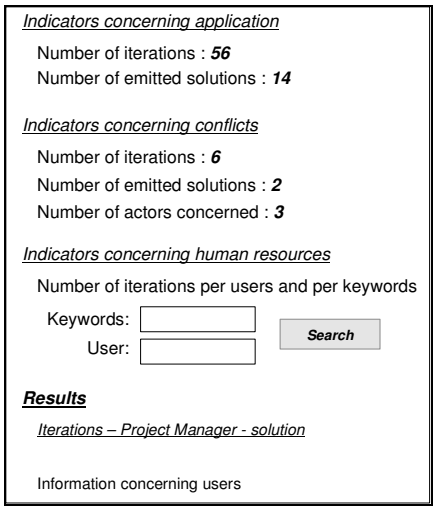

Figure 4: GUI for the consultation of the performance indicators in CO²MED

In this particular context, the control of the technical fields implied in the project and the comprehension of specificities of each project are necessary to ensure a good comprehension of the group. Indeed, competence on a project is built progressively, "it is in its unfolding even, as the various aspects are explored, that the compromises are analyzed and that the collective memory on the singular adventure is constituted" [2].

In the case of a conflict resolution, standard process cannot be defined and the actors' strategy, their determination and their capacities of dynamic adaptation to the situation are central. Competence is expressed here while adapting and selecting the steps and solutions according to the target, of the specific context of the project but also of the as-is organization. Thus, in this particular context of work, it is necessary identify the actors who are potentially most interested and interesting to facilitate the conflicts resolution and to create a synergy to this resolution. The actors' capacities to collaborate have to be highlighted. To adopt a dynamic vision of these capacities to collaborate, CO²MED uses a structure and a representation of the various exchanges between the actors invited to solve a conflict. This structuring, also existing in the theories of the negotiation [20], aims at showing the sequence of the answers to the various iterations, and permit to present the traceability of the knowledge exchanged by taking of account the type of the contribution (argumentation/critic of solution or contribution of solution) in the construction of the tree structures. The visual analysis of these sequences offers the opportunity to distinguish 2 cases (figure 5):

Case n°1

A strong vertical deployment corresponds to a phase of mediation where one attends a significant production of solutions. This phase appears in particular at the beginning of conflict resolution, when the causes of this one are not exactly identified. Some of these new solutions will find a development as presented in the case n°2.

Case n°2

A strong horizontal development of the tree structure corresponds to a process of discussion on a given proposal. The actors generate iterations by explaining, arguing or revoking the solution suggested.

This structuring of the tree gives dynamic information and updates the capacities to collaborate of the actors solving the conflict. Indeed, a strong vertical deployment of the tree structure translates a good level of creativity among various protagonists but their capacity to collaborate is relatively low since they do not manage to converge towards a single solution. This can express a lack of interest to the objective of conflict resolution. In the same way, a tree structure developed horizontally highlights sterility in the actors' capacity to collaborate. This representation made up of argumentations and against-argumentations can be characterized by the presence of personalities with strong character, wanting absolutely to impose their point of sight.

This real time visualization of the exchanges animating the conflict resolution, associated the consultation of the performance indicators relating to the participation of the actors in the discussions, makes it possible to the project manager to make the decisions which are essential as for the withdrawal or the addition actors in the conflict resolution process. It can also underline the increase in competencies of actors being expressed more and more on a field of expertise not being identified like theirs. This software application answers thus the challenges of evolution and dynamic update of competencies, in point of view of the level of expertise as their capacity to collaborate. Nevertheless, even if the access and the representation of these competencies fields can prove to be easy for management of the design activity at the operational level, it is not the same if one addresses to tactical or strategic levels. In this way, a fusion between the two software applications presented (PEGASE and CO²MED) would permit to answer completely the four challenges previously evoked, while guaranteeing a dynamic evaluation of the capacity of the actors of the design to collaborate.

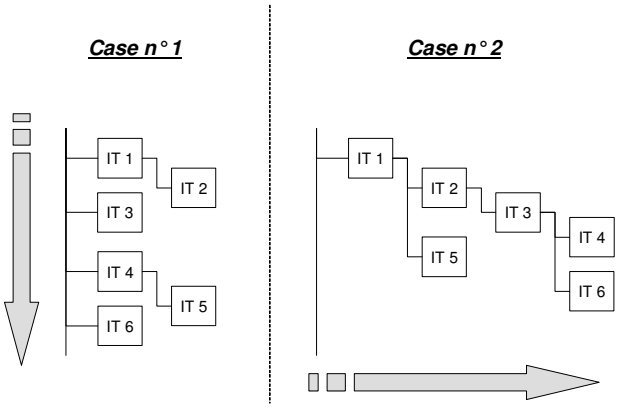

Figure 5: Logical representations of the sequence of the exchanges in the form of iterations

5 CONCLUSION

In a context where the search for design activity performance is constant, an effective management of competencies of the actors to be implied in a design project seems today to have become a decisive point. In this paper, we wondered answer the various challenges concerned with this competencies management that are the provision, the dynamic evolution, the collection of the data and the confidentiality, within the framework of the individual expertises but also within the framework of collaborations specific to the new forms of design currently used.

We tried to bring various answers to these challenges, via the use of a "network" approach allowing project managers to chart the relations existing between actors and thus their way of collaborating via the use of competencies matrix to chart these competencies and via the use of prototypes of software to assist competencies management.

Future researches will try to improve the assistance with competencies management bound for the heads of design projects. This work can thus relate to the precise quantification of the level of collaboration between actors, like on the evaluation of collaborative competencies proposing in a design project, in correlation with researchers in social sciences. From a tools point of view, we showed how our complementary applications for the dynamic management of the actors of the design could support decision-making. The next step in our research will be the integration of these software applications.

6 ACKNOWLEDGMENTS

Many thanks to Alstom Moteurs Company (Nancy, France) which provided us the industrial case study, and particularly to the employees of the design and engineering department for their collaboration in the establishment of the competencies matrix.

7 REFERENCES

[1] Longueville B., Le Cardinal J. and Bocquet J-C., 2002, Decision based knowledge management for design project of innovative products, International Design Conference, Dubrovnik, Croatia, 14-17 May.

[2] Garel G., Giard V. and Midler C., 2001, Management de projet et gestion des ressources humaines, IAE de Paris, Cahiers de recherche GREGOR.

[3] Robin V., Rose B. and Girard P., 2007, Modelling collaborative knowledge to support engineering design project manager, Computers in Industry, vol. 58-2, pp 188-198.

[4] Rose B., Robin V., Girard P. and Lombard M., 2007, Management of engineering design process in collaborative situation, International Journal of Product Lifecycle Management, vol. 2-1, pp.84-103.

[5] Lindgren R, 2002, Competence studies, Gothenburg Studies in Informatics, Report 23, June.

[6] Hao, Q., Shen, W., Zhang, Z., Park, S.W., Lee, J.K., 2006, "Agent-based collaborative product design engineering: An industrial case study," Computers in Industry, 57, pp. 26-38.

[7] Stenmarck D., 2004, Managing knowledge through everyday activity, Online Information 2004.

[8] Girard P., Robin V., 2006, Analysis of collaboration for project design management, Computers in Industry, Vol. 57, n°8-9, pp. 817–826.

[9] Robin V., Rose B. and Girard P., 2007, Modelling collaborative knowledge to support engineering design project manager, Computers in Industry, vol. 58-2, pp 188-198.

[10] Hakansson H., Johanson J., 1992, A Model of Industrial Networks, Routledge, ed. by B. Axelsson and G. Easton.

[11] Nowak P., Rose B., Saint-Marc L., Callot M., Eynard B., Gzara-Yesilbas L. and Lombard M., 2004, Towards a design process model enabling the integration of product, process and organisation, 5th International Conference Integrated Design and Manufacturing in Mechanical Engineering, 5-7 April, Bath, UK.

[12] Robin V., Rose B., Girard P. and Lombard M., 2006, Management of Engineering Design Process in Collaborative Situation, Advances in Design, Eds Springer, dir. Hoda A. ElMaraghy, Waguih H. ElMaraghy, pp. 257-269.

[13] Darses F., Détienne F. and Visser W., 2001, Assister la conception : perspectives pour la psychologie cognitive ergonomique, ÉPIQUE 2001, Proceeding of the « Journées d'étude en Psychologie ergonomique », Nantes, France, 29-30 october, http://www-sop.inria.fr/acacia/gtpe/GTPE-Actes-epique-2001-tdm.html

[14] Gzara L., Rose B. and Lombard M., 2006, Specification of a repository to support collaborative knowledge exchanges in IPPOP project, Computers in Industry, vol. 57, pp. 690–710.

[15] Hadj Hamou K., Caillaud E., 2004, Cooperative design : a framework for a competency-base approach", 5th International Conference Integrated Design and Manufacturing in Mechanical Engineering, 5-7 April, Bath, UK.

[16] Rakoto H., Clermont P. and Geneste L., 2002, Le retour d'expérience, un processus soci-technique, 1ier Colloque du groupe de travail Gestion des Compétences et des Connaissances en Génie Industriel, « Vers l'articulation entre Compétences et Connaissances », Nantes France.

[17] IPPOP, « Intégration Produit Processus et Organisation pour l'amélioration de la Performance en conception», RNTL project. Website IPPOP : http://ippop.laps.u-bordeaux1.fr/index.php

[18] Rose B., 2004, « Proposition d'un référentiel support à la conception collaborative : CO²MED (COllaborative COnflict Management in Engineering Design), Prototype logiciel dans le cadre du projet IPPOP », Thèse de doctorat de l'université Henry Poincaré Nancy 1.

[19] Rose B., Lombard M., 2003, « Gestion du cycle de vie d'échanges formalisés en conception collaborative : capitalisation et évaluation », dans « De la GDT au PLM », Special issue of Revue internationale de CFAO et d'informatique graphique, coordonné par Eynard B. et Caillaud E., Vol 18-4.

[20] Baker M.J., 1993, Dialogic Learning: Negotiation and Argumentation as Mediating Mechanisms". Proceedings of AI-ED '93: World Conference on Artificial Intelligence in Education, Edinburgh, UK.