DEVELOPMENT OF A REFERENCE MODEL FOR INTEGRATING PRODUCT DEVELOPMENT PROCESS-RELATED KNOWLEDGE

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Abstract *- The development of new products has become the focal point of industrial competitiveness and today is considered a business process based on multidisciplinary knowledge. Because the success of this process depends on the systematic management of knowledge, a solution to help professionals and researchers interact, thereby facilitating their integration is to map the product development process by creating a reference model. This model allows for the structured storage of explicit knowledge relating to a business process. Having only a partial vision of the product development process may lead to a limited understanding of it, hindering the integration of the activities and professionals involved in the process. Therefore, three research groups working in the area of product development have formed a community for systematic sharing of knowledge through a web portal. This sharing enables each group to increase its learning capacity and simultaneously generate new competencies. The community's main challenge – to create a synthesis of its knowledge about product development – has led it to develop a reference model to retain knowledge concerning a theoretical product development process. The reference model should contain all the results of former researches obtained by the members of the community. The purpose of this article is to present the creation of a reference model for the product development process within the environment of a community of practice.*

Key words: *reference model, product development process, and community of practice*

1. Introduction

The importance of the product development process has been emphasized by many authors, mainly due to the significant impact it exerts on costs, quality, customer satisfaction, and the competitive advantage of companies (see, for instance, DECHAMPS, J.P. & NAYA, 1997). However, it is a difficult process to manage because it is essentially creative, depending on the skills and knowledge of different areas and involving a high volume of complex information regarding the market, suppliers, technological possibilities and production capacities (COOPER, 2003).

These factors lead to partial views, originating from the difficulties of understanding the strategic importance and recognizing the scope of product development for the company. These partial visions have their own vocabulary and values, deriving from the various areas of knowledge in which the methods, tools and concepts are created.

When transported to practice, i.e., to everyday activities, these partial visions give rise to problems and inefficiencies in the product development process, making it difficult for the professionals involved in the activity to become integrated. This scenario can also be seen in the field of education and research, as well as in the publications and various materials available in the literature about this process, which is treated in an isolated manner by the different areas of specialized knowledge.

To minimize the limitations brought about by these partial, or incomplete, visions, several product development researchers from three different institutions in Brazil launched a cooperative effort aimed at jointly creating a community of researchers and company professionals concerned with the management of the product development process (PDP). One of the main objectives of this community of practice is to facilitate the development of joint research and interaction between university and companies, aligning the research projects to the needs of national industry, generating knowledge and a shared vision of this process (MOSCONI et al., 2002).

To achieve this purpose, one of the main goals established was the creation of PDP reference models. As stated initially, these models describe the PDP and serve as references for companies and professionals to develop products and aid the implementation of improvements, tools and methodologies. The existence of a reference model provides a single and unified vision of the PDP, leveling the available knowledge among the actors that participate in a specific development.

The purpose of this article is to describe the experience of the creation of a reference model within the environment of a community of practice, to which each institution contributed with its specific knowledge and competencies that are complementary to each other and encompass all the aspects of the PDP. A comprehensive view is also given of the reference model's structure and of how its representation is being defined, as well as results and future perspectives.

The methodological approach of this study consists of an action research, which, according to THIOLLENT (1997), is conceived and carried out in close association with an action or with the solution to a collective problem, in which the researchers and participants representative of the situation or problem are involved cooperatively or participatively, making interventions throughout the development of the work.

Item 2, therefore, presents concepts that underpin the theoretical basis of this work, encompassing the vision from the standpoint of product development, reference models and communities of practice. Item 3 then describes the community of practice in product development, while item 4 presents the creation process of the reference model, describing its main elements, and item 5 presents our main conclusions, commenting on the results obtained and the next steps.

2. Theoretical foundation

2.1 Product development as a process

Understanding and defining product development involves the same difficulty inherent to any issue relating to the study of organizations, i.e., understanding the complexity of the organizational system. An organization can be seen as a system composed of a set of functions, people and machines linked to each other by intensive, varied and complex relations (AMARAL, 1997).

Product development can be defined, as proposed by CLARK & FUJIMOTO (1991), as a process whereby an organization transforms data about market opportunities and technical possibilities into the manufacture of a commercial product.

HAMMER & CHAMPY (1994) define a business process as a set of activities with one or more inputs, which creates an output of value for the customer. VERNADAT (1996) defines process, more precisely, as a set of activities partially ordered into a logical sequence and executed to result in a given purpose, i.e., to achieve a foreseen result.

One common point to note in these definitions is the multifunctional nature of the process, i.e., a business process is not restricted to one functional unit of the company; on the contrary, it crosses over various areas of the company (ROZENFELD 1996; DAVENPORT 1994; and, more recently, CRUZ, 2003).

More recently, there has been a strong tendency to incorporate into this definition activities relating to product updating/improvement and to all the aspects of its removal from the market and its recycling; in other words, considering all the phases of the product's life (ROZENFELD et al., 2000).

2.2 Phases of the Product Development Process

The PDP is typically structured into various phases or stages in order to facilitate the understanding of and control over the process. A phase is marked by the conclusion of one or of a set of important results of the project (PMBOK, 2000).

Several authors present different phase structures for PDPs. To cite the most classic ones, see PUGH (1978), CLARK & FUJIMOTO (1991), WHEELWRIGHT & CLARK (1992), CLAUSING (1998), DUCHAMP & NAYA (1997). There are many differences among them, which can be explained by various factors, one of which is the type of product that is used as the basis (its technology, complexity, etc.) and another the set of characteristics by which the companies are considered.

Some authors further expand the scope of product development, including strategic planning activities at the beginning of the process and activities involving production monitoring and removal of the product from the market at the other extreme (ROZENFELD et al., 2000).

2.3 Reference models

A model can be defined as "a representation (with a greater or lesser degree of formalism) of the abstraction of a reality expressed in some specific type of formalism" (VERNADAT, 1996). A model of a company is a specific type of model made up of a set of models that seek to represent the different visions of the company. According to VERNADAT (1996), "a model of a company is a consistent and complementary set of models describing various aspects of an organization, whose objective is to help one or more company users in some purpose".

An interesting aspect to be noted in this definition is the idea of a "set" of models. The reality with which a model of a company has to deal with is extremely complex. Therefore, it is impossible to represent all these elements in a single representation. The solution involves the construction of models that represent specific aspects of the company, each commonly called a specific "vision" of the company. Thus, with a consistent and complementary set of visions, it is possible to clearly represent the most complex reality, in short, the company (AMARAL, 2002).

In the area of studies about company modeling, there is a common distinction between a reference model and a specific model, the latter also being called simply model or company model (see KELLER & TEUFEL, 1998; and SCHEER, 1998). A company model is called specific when it describes the business process of a specific company and is applied in that context. The term reference model refers to broader and more general application models, which are built for use by different companies and/or contexts, serving as references for the development of specific models. Some methods to build company models are described below.

2.4 Communities of practice

Communities of practice are groups of people with common interests in a technology, company, product or knowledge domain. Their members interact to solve problems, generating knowledge for themselves and, if the community exists within a corporate environment, for the organization. In other words, what keeps people connected to each other is their common interests in learning and personal development (SVEIBY apud MUNDIN, 2001).

Communities of practice presuppose three basic elements, listed below (WENGER et al., 2002):

- Domain: the subject the community deals with, shares and about which it creates knowledge.
- Community: people that interact and create relations with each other around a domain.
- Practice: action developed by the community, whereby its members learn together how to work on and deal with the issues in which they share a common interest.

WENGER et al. (2002) point out that, albeit not a new concept, communities of practice have recently assumed a special importance as the result of the perception that "knowledge is an act of participation" and that the ones who should generate knowledge are those who produce it and use it daily. Communities potentiate this process within organizations, facilitating the creation and transfer of knowledge by simultaneously making feasible informal channels of communication among several departments and with outside organizations, since, by definition, the members of a community are not restricted to a given organization (WENGER et al., 2002).

Organizations that act in state-of-the-art areas make intensive use of knowledge and can therefore benefit enormously from the existence of communities of practice. The question is how to encourage them to do so.

As mechanisms of motivation and articulation of communities, SCHEIN (1998) and TERRA (2002) highlight the organizational structure, organizational systems and procedures, physical space and its use, stories, myths, legends and parables about given events or people, and formal definitions of the organization's philosophy.

WENGER et al. (2002) point out that information technology (IT) can be an extremely important tool for communities of practice because, although not mandatory, it can potentiate the results of the initiatives of knowledge sharing and exchange. IT is a powerful facilitator in the application and generation of new ideas for products and services, enhancing the productivity of communities of practice, putting people in contact with explicit knowledge, and stimulating the generation of ideas and insights.

The next section discusses the creation of a community of practice made up of a group of people sharing common interests, who got together to create new knowledge, based on the practice and/or study of a specific theme, in this case, about the product development process.

3. Creation of a community of practice on product development

The researchers who jointly set up the community of practice on product development have maintained relations since 1998. Throughout this period, they had always intended to develop cooperative work but had not done so earlier for lack of a concrete work project with common objectives, goals and resources.

In the year 2001, however, an opportunity presented itself through the Program of Academic Cooperation (PROCAD), supported by CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Coordination of Improvement of University-Educated People). A project was prepared with the purpose of sharing their knowledge to acquire a broader, integrated and multidisciplinary vision of this process, which would allow for the development of effectively joint projects.

The founders of the community of practice on product development belong to the following institutions:

- NeDIP – EMC/UFSC (Nucleus of Integrated Product Development – Department of Mechanical Engineering – Federal University of Santa Catarina),
- GEPEQ – DEP/UFSCar (Study and Research Group on Quality – Department of Production Engineering – Federal University of São Carlos), and
- Grupo EI – NUMA-EESC/USP (Integrated Engineering Group/Nucleus of Advanced Manufacturing – São Carlos School of Engineering – University of São Paulo).

The relations existing prior to the project were mostly of a professional and temporary nature, involving mainly academic activities and meetings at congresses. However, they were essential to the formation of the community of practice, for the mutual respect of those involved was a fundamental factor underpinning the confidence and certainty each of the coordinators displayed to persuade the other professors and researchers in their group to participate in the project. Moreover, it also facilitated the communication and openness between the people of these institutions.

The founding research groups of the community of practice act within the realm of themes relating to product development, but with complementary perspectives. The NeDIP has a lot of experience in the development and application of PDP methods and techniques, more specifically in product design. GEPEQ, on the other hand, has experience in making diagnoses and surveys of the needs of companies that develop products. The Integrated Engineering Group, in turn, has a tradition in research on systems to aid PDP management.

To facilitate the sharing of knowledge among the members of the community of practice, an Internet-based portal was set up and called PDPNet (Network of Knowledge in the Product Development Process). This portal introduces the

members of the groups, describing their interests and their ongoing researches. In addition, the portal offers functionalities for chats, forums for discussion on themes of interest to the members, permits the sharing of bibliographic references, etc. It should be noted that this portal has also enabled researchers from other institutions and company professionals working with product development to share their knowledge with the community. The portal is available on the Internet at: http://www.pdp.org.br.

Among several goals and activities developed by the community, one of the most important ones was the joint creation of reference models for product development processes, which motivated and awoke great interest among the participants, as will be described in the following section.

4. The reference model for the product development process

The first reference model developed aimed to be as generic as possible, so that it could be used in didactic/academic activities and become a "reference" for the derivation of other models focusing more directly on a sector or a specific type of product.

A description is given below of the dynamics involved in the creation of the model, and of the model itself.

4.1 Activities involved in the creation of the reference model

The product development process model was one of the first activities developed, and was begun during the first official meeting of the project, held in the city of São Carlos. All the researchers involved attended the meeting, totaling about 35 professors and post-graduate students. The meeting opened with an official introduction of the groups, made by their respective coordinators. This was followed by a series of activities lasting for the three days of the meeting, with the researchers working about 8 hours per day. Discussions were held about the main references in product development used by each group, and an initial list of key words and mechanisms for sharing information were defined.

The discussion of the model played a prominent role, taking up about 12 hours and officially concluding the work. At the start of the discussions about the model, therefore, the researchers already knew more about the groups and researchers involved in the project and some of the concepts and key-words had already been consolidated during the intensive contact of the previous days. The discussion of the model began with each group presenting its definition of the reference model and the models they already possessed.

All this preparation proved essential since, as was later confirmed, the discussion about the reference model was the most challenging. From the start it was quite clear that each of the participating institutions has very distinct visions, starting from the very concept of what a reference model should be and what level of details it should reach, especially given their main competencies and lines of action. Given the scope and number of participants at this first meting, it was impossible to discuss the semantic and conceptual details that underpinned the different visions. The eagerness of each research group to define and structure these visions in its own way led to a heated discussion during the meeting, hindering the progress of the work. Several concepts were discussed at the same time, with conversations and circles of discussion occurring simultaneously. The problem was soon identified and, gradually, the objective of the meeting was altered. The idea gained force that a minimum consensus had to be reached about the model, which could guide the groups' future work. The model was separated into three large macro-phases, with beginning and end clearly defined by consensus, namely: predevelopment, development and post-development.

The first description of each macro-phase was allocated to specific research groups, which took it upon themselves to develop a proposal for discussion in physically attended meetings with researchers from the other groups. The Integrated Engineering Group was in charge of preparing the initial predevelopment proposal, while the NeDIP would prepare the proposal for development and GEPEQ that of post-development. The research groups in charge of revisions would receive the proposals beforehand and hold an internal discussion with all their researchers to obtain a consensus about possible alterations to the proposal. Representatives of each reviewing group, usually a team composed of the coordinator and one or two post-graduate students, participated in physically attended meetings of the three groups, during which these questions were debated until a consensus was reached. This strategy was very useful and beneficial for the project, allowing for in-depth discussions of all the phases of the model, respecting the natural competencies of each research group and promoting the sharing of knowledge, both among the groups and inside each group. A big surprise was reserved for the intra-group discussions. Contrary to expectations, for at least two of the groups, these discussions contributed greatly to strengthen the bonds and increase the exchange of information among the researchers, particularly the professors of the research groups themselves.

The negative side was that the construction of the model was a harder and slower task than foreseen in the original project. At first, this appeared to be a problem. However, an analysis of the situation upon conclusion of the project led to this aspect being reconsidered, changing it to a very positive sign, since it reflected a real learning situation for all the researchers. The final result was a very different model from the ones that existed in each group, attesting to the generation of new knowledge and the diffusion of best practices systematized during years of research carried out by each group.

To conduct the meetings and discussions it was necessary to adopt an initial means of representation, i.e., a convention of how to describe the process. It was clear that the primary objective was to develop the content and not the form of the model. Therefore, the chosen representation had to meet the following requisites: easy to understand by everyone in the groups, easy exchange and manipulation of files among the groups, easy to read, containing only the

essential dimensions. The solution adopted was the representation of the model on charts, using the Excel software, in which the activities were listed in columns, followed by the necessary inputs, outputs, methodologies and tools, see the Figure 1. This format meet the various requisites, but presented two major deficiencies: the arrangement of the activities on lines precluded representation of the time dimension, leading to a reasoning of chronological and serial order between the activities. This limitation was the source of much discussion about the definition of the activities. The second inconvenience was the difficulty of representing the various occurrences of the same information or tool in the other versions, generating inconsistencies in the dimensions: inputs, outputs and tools. Although these limitations were significant, for the purpose of obtaining an initial version, the format proved sufficient since, in a way, although it brought problems, it also prioritized a discussion about the activities and phases. This dimension of the model was therefore exhaustively discussed and the information, tools and methodologies were defined in greater detail at a later date.

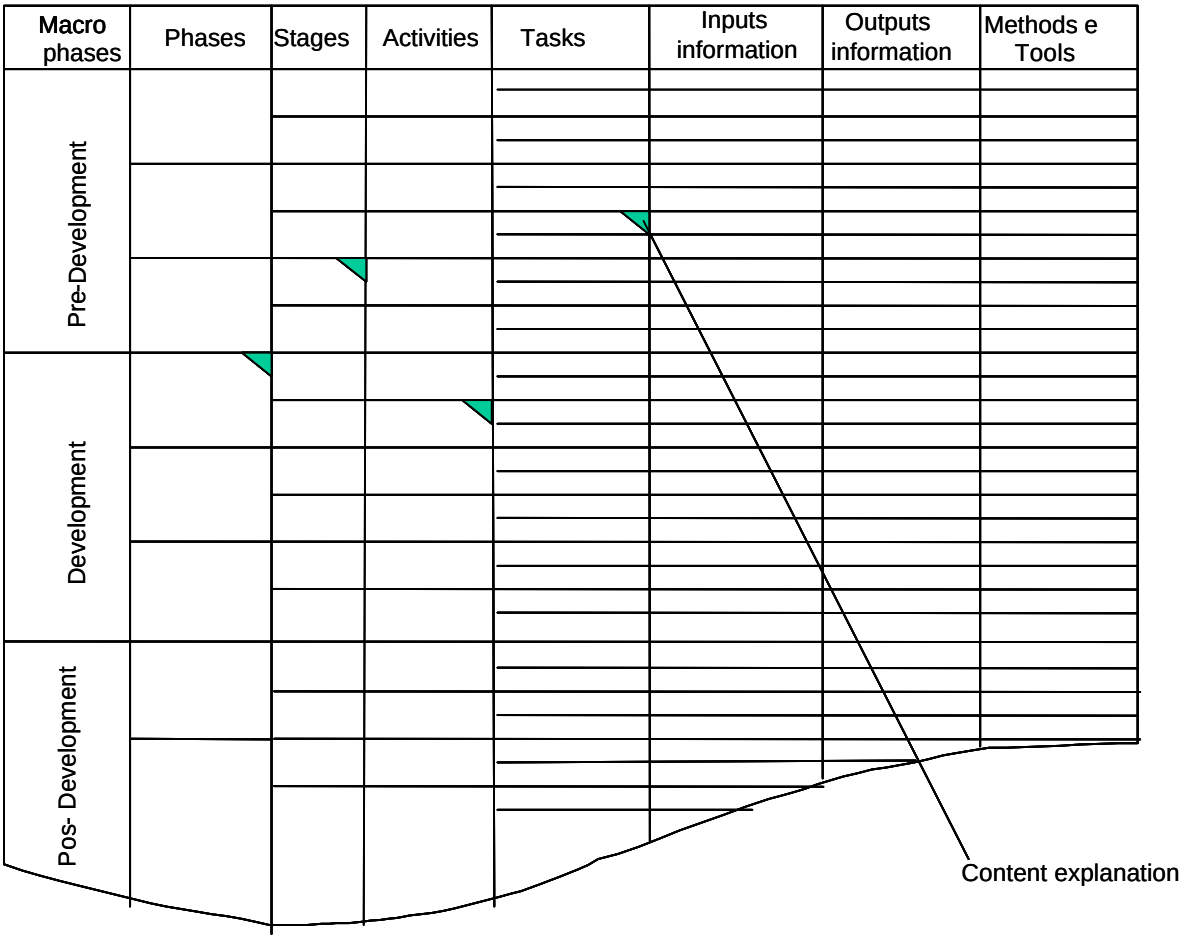

Figure 1 - Structure of the Reference Model

Concomitant to this exhaustive work of discussion of the main reference model, the research groups began research projects to adapt this model under construction to specific applications. A joint project between the NeDIP and GEPEQ groups began the development of a reference model for the development of agro industrial products. A researcher of the NeDIP group developed a reference model for farming machines. Researchers of the IE Group, with the support of two researchers from NeDIP, began the development of a reference model for mechanical-electronic products for technology-based companies, and thus, three specific models deriving from the main model followed, in which the researchers applied all the experience generated during the discussions of the main model.

In December 2002, after several versions of each of the macro-phases had been generated, an initial version of the model was produced containing the dimensions, activities and input and output information represented on an Excel chart. While some final aspects of this model were under discussion, a work group was formed with representatives of the three groups for the development of a final form of representation of the model. This group started from a representation proposal created by a researcher of NeDIP for one of the partial models, demonstrating the importance of parallel work between the general model and its applications. This group is currently working to finalize the model's representation according to this new format, which will allow for aspects currently neglected by the representation on charts to be represented, such as the dimension of time, the dimension of phase revision, and others that are necessary for the reference model to aid professionals and researchers interested in the area of product development.

The following sections provide a general description of the content of the reference model developed.

4.2. Description of the reference model

In the main view of activities, the model is divided into the following levels: macro-phase, phase, stages and activities. **Figure 1** gives a schematic representation of the macro-phase levels, in the upper portion of the figure and of the phase, in the center and lower portion. Stages and activities were defined for each of the phases described in the center of the figure.

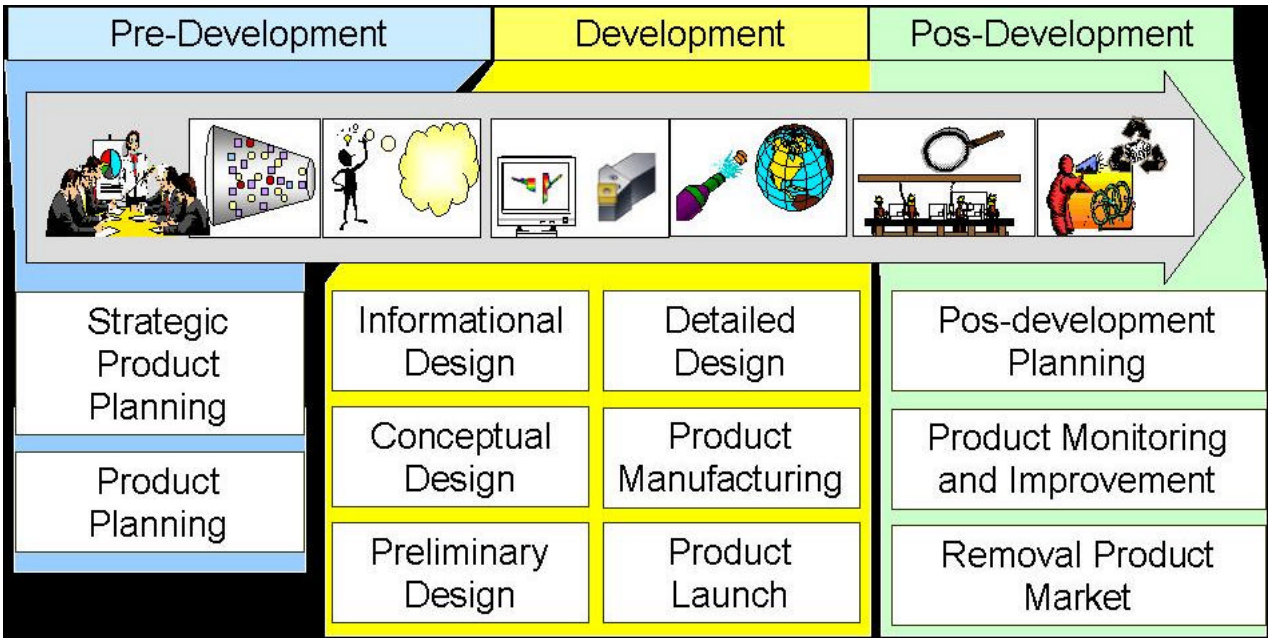

Figure 2 - General view of the model

The “Pre-development” macro-phase contains the definition of the product to be developed, i.e., the definition of the scope of the development project (team, results, restrictions, etc.), the economic evaluation of the project, project capacity and risk evaluations, definition of indicators to monitor the project, and definition of business plans. This is what, in the model, is called Product Planning. Because it is a process integrated with the company’s mission and strategic direction, this macro-phase considers the possibility of creating a product family. Hence, there is a phase prior to Product Planning called Strategic Product Planning, which consists of a revision of the company’s Strategic Planning and its unfolding, generating a portfolio of products that can fulfill the goals defined in this strategic plan. This portfolio will contain the products that are to be developed, including an initial description of their characteristics and stating whether it involves a completely new design, an update, or if it is part of a family of products. The portfolio also states the date when the planning phase of each of the products will begin.

A whole range of information about the design theme in question and its subsequent interpretation is collected in the Informational Design phase. The design procedures consist mainly of making surveys at clients of the needs and desire to be met by the design. These needs are analyzed and then transformed into technical specifications to be followed in the design. The Conceptual Design phase, based on the information obtained in the previous design phase, proposes the concept to be adopted by the product. A synthesis is made of the structure of functions to be performed by the product, the search for incipient solutions for each of these functions, the subsequent proposal for design alternatives and, finally, the selection of those that are the most consonant with the consumer’s needs, according to the surveys performed in the previous phase. In the Preliminary Design phase, based on knowledge of the concept and the product’s functional structure, the product is dimensioned and the materials, shapes, components, manufacturing and assembly processes etc. for it are selected. This phase has a more interactive nature, since a single alteration in a component may lead to various other alterations in other parts of the product. At the end of this phase, the products are completely structured. In the Detailed Design phase, the final Design phase, the arrangement, shape, dimensions and tolerances of all the components are finally set, together with the definition and planning of the production processes. The conclusion of the PDP is marked by the official Product Launch phase.

In the "Pos-development" phase, an initial the Pos-development Planning phase is done to define how the product will be monitored and removed from the market. The teams and resources required for engineering alterations must be defined, aiming at corrections of potential failures and/or the addition of improvements required by the customers. Goals and indices are also defined that indicate when the product should be removed from the market. At the end of this planning, the Product Monitoring and Improvement phase begins, when these teams carry out the maintenance and improvement of the product, giving special attention to the systematization of design-related knowledge and best practices that should serve as feedback to all the professionals involved in the development. This phase lasts up to the moment when the product reaches its goals and the team that manages the product portfolio decides to discontinue it.

The phase of Removal of the Product from the Market then begins, during which the project is officially closed, involving all the actions relating to correct environmental disposal, destination of parts and product stock, auditing for the general balance of knowledge acquired with the product, and correct filing of product information.

Information (input and output), tools and methods required to carry out each activity are also described. In all, the model has 276 activities, 171 information (inputs and outputs) and 110 methods and techniques used by 12 different organization units, which, for lack of space, will not be presented here, because this not being the focus of this article.

5. Conclusions, final remarks and next steps

The creation of the model has enabled the researchers, specialists in given phases and parts of this process, to contribute their knowledge for the creation of a joint, strongly interdisciplinary model.

The reference model of the PDP has been the greatest aggregator of content and knowledge in the community of practice, since it aggregates the knowledge of each of the members in the activities of the PDP, from the company's strategic definitions to the planning of aspects relating to the discontinuation of the production of the developed products and its removal from the market.

Hence, the creation of this reference model has been fundamental for the groups to formalize their specific knowledge about the process and learn from each other, since their knowledge is complementary.

This experience demonstrates that an important form of fomenting a community of practice is through the definition of common objectives among people who are beginning a relationship. While theory indicates that such relationships can spring up spontaneously without this aspect, this experience has demonstrated that the existence of an objective is fundamental to foment them within existing organizations. Common objectives "encourage" people to establish a minimum of contacts and to share knowledge, which is indispensable to generate the future relationship and collaboration.

The discussions about specific points of the model allowed for the uniformization of the language and the exchange of experiences, bibliographies and ideas, besides greater proximity in terms of personal relationships.

In future, the model should be used to facilitate the teaching of company staff on a technical level, allowing for action in activities of extension in University-Company integration. The model should also allow for the development of several specific models for different industrial sectors and/or product classes, for the community also has the goal of continuing to unfold this process, mapping the various dimensions of each of the activities, for instance, the information required, the resources they consume, the costs of the activities, etc.

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