

PROPOSAL OF AN EVALUATION MODEL OF KNOWLEDGE MANAGEMENT IN THE PRODUCT DEVELOPMENT PROCESS

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Abstract. *This article discusses the application of a knowledge management (KM) evaluation model of the product development (PD) process, which focuses on mapping the occurrence of four types of conversion of knowledge into the four dimensions that make up this process. The model is supported by the literature's state of the art on KM and PD, from which hypotheses and best practices are drawn that indicate conversions of knowledge into given dimensions of PD. This model proves effective for the construction of a broad vision regarding the situation of KM in a company's PD process. The application of this model to a thorough analysis of the PD of a truck and bus manufacturer proved its practical viability and particular usefulness in identifying and highlighting the gaps in the KM of this company's PD process.*

Keywords. *Product Development, Knowledge Management, Evaluation Model, Automotive Industry*

1. Introduction

The two themes discussed herein are strongly correlated, to wit, knowledge management (KM) and the product development (PD) process. This correlation directs the focus of this research, which is to study PD as a business process comprising four dimensions, wherein four types of knowledge conversion can occur.

Based on consolidated theoretical approaches (Clark & Wheelwright, 1992; Clausing, 1994; Prasad, 1996), the PD process can be stated to consist of four dimensions that must function in an integrated manner, i.e., Strategy (which involves the perspectives of portfolio management, performance evaluation, interfunctional relations, and partnerships with suppliers), Organization (involving the perspectives of organizational structure, leadership, group work culture, and the learning conditions); Activities / Information (the set of specific operational activities carried out in the PD process and the corresponding information that is handled); and Resources (the techniques, methods, tools and systems employed to support PD).

There is a continuous creation and exchange of knowledge in these dimensions and the manner in which this occurs influences knowledge management (KM) decisively in the PD process. These exchanges take place through four conversions (Nonaka & Takeuchi, 1995): – knowledge transmitted directly among people (Socialization); – documentation of knowledge (Externalization); – grouping of the documents (Combination); and – study of the documents (Internalization).

In an extensive bibliographical study guided by the literature's state of the art on KM and PD, several references were found that prove directly (best practices) or indirectly (hypotheses) one or more correlations of the dimensions of the PD process with knowledge conversions. Based on this study, a model was built to evaluate KM of the PD process, structured upon an analysis and investigation of the correlations between conversions and dimensions throughout this process.

Therefore, the main objective of this article is to demonstrate the practical feasibility of this model, seeking answers to the following question: How can this model be applied to the practical evaluation of KM in a company's PD process?

The main rationale for engaging in this work lies in the fact that the relationship between PD and KM, albeit perceived and commented on in the literature, has been dealt with in a fragmented and fairly unsystematic way, and to date no model exists that enables people and companies to evaluate and, based on such an evaluation, to better manage this relation.

The evaluation model of KM in PD is outlined and discussed under topic two, which shows its application potential and its limitations. The two principal axes that make up the model – PD and its dimensions and KM and conversions of knowledge – are also briefly explained under this topic.

Topic three discusses the research methodology upon which this study was structured. The model's application, and the case study (description, results and discussion), are presented under topic four. Lastly, topic five concludes the article with our final considerations regarding this work.

2. Evaluation model of knowledge management in the product development process

An earlier paper (Silva & Rozenfeld, 2001a, 2001b) engaged in a detailed discussion of the theoretical fundamentals of PD (and its dimensions) and KM (conversions of knowledge), and of how the correlations between dimensions and conversions were worked in order to build this evaluation model.

The following sub-topics briefly outline the main points of this theoretical context, duly updated, while topic four of this article presents the model in such a way as to illustrate its practical application.

2.1. Construction of the model

This article briefly presents the bibliographical study mentioned in the introduction, which yielded the best practices and hypotheses that form the basis of the evaluation model of KM in the PD process, providing the model with the backing required to investigate the relationships between conversions and dimensions throughout this process.

The four types of knowledge conversion (Socialization, Externalization, Combination, and Internalization) may occur in each dimension of PD (Strategy, Organization, Activities, and Resources). Each of the perspectives, activities, resources of these four dimensions can be correlated with one or more knowledge conversions (see examples under this same sub-topic). The set of these relations possesses a matrix shape, which is schematized in Tab. (1), in which the crossing of the conversions with the dimensions (perspectives, activities and resources) are validated by the hypotheses and best practices found in and taken from the literature.

Table 1. Evaluation model of KM in the PD process.

PD dimensions (n) (see sub-topic 2.2)	Conversions of knowledge (see sub-topic 2.3)			
	Socialization	Externalization	Combination	Internalization
Strategy (4)	10HT 1BP	9HT 2BP	9HT 1BP	10HT 1BP
Organization (4)	12HT 6BP	11HT 6BP	8HT 2BP	12HT 4BP
Activities (13)	26HT 2BP	34HT 2BP	21HT	21HT 1BP
Resources (7)	9HT 3BP	19HT 3BP	9HT 2BP	13HT 3BP

Note: n = number of perspectives, activities or resources of the dimension; HT = hypotheses; BP = best practices

This set, therefore, represents the content of the model. In other words, this model represents a variety of hypotheses and best practices relating to the types of conversions that may occur in each of the perspectives, activities and resources that make up the dimensions of the PD process.

This evaluation model is applied by means of interviews with people involved in the PD process, having different specializations, experience with PD, and hierarchical levels.

Merely for the sake of illustration, two examples are given below, taken from the model's various hypotheses and best practices, which refer, respectively, to the perspective of Execution of the work of leadership of PD, in the Organization dimension, and the activity of Elaboration, construction and testing of prototypes, in the Activities /Information dimension:

Leaders of a PD project, who normally have a generalist profile, handle knowledge more informally and intuitively (tacitly) and with a strong content based on experience (perception) and on past cases (Fleck, 1996; Brockmann & Simmonds, 1997; Brockmann & Anthony, 1998). Hence, it is to be expected that a leader values Socialization and Externalization, because these forms of conversion are closer to the tacit way in which a leader works with knowledge.

Prototypes may take on substantial importance in the viewing and learning of solutions (Internalization) (Leonard, 1995), in the representation of knowledge, in the explanation of solutions and proposals about the product / project (Externalization) (Bolisani & Scarso, 1999), and as a catalyzer of the exchanges of tacit knowledge (Socialization) among members of a PD design team and also between them and suppliers and clients (Mascitelli, 2000).

The evaluation model of KM in PD starts from the assumption that initiatives of knowledge conversions in the PD process already exist. The focus lies in considering these initiatives and mapping them, understanding how they are made and detecting existing gaps (both of conversions that are poorly effected and of those that are not occurring in certain dimensions of PD, attempting to find explanations for this situation).

2.2. Product development and its dimensions

PD is a typically interfunctional process in which the interfaces between functions occur in an increasingly parallel manner with a faster exchange of information (Davenport, 1994). Following this approach of the process, the interest in the focus of this work is to detail its four dimensions. The major contribution lies in discussing specific problems residing in these elements or dimensions without losing the vision of the whole, the "single image", given by the process (Rozenfeld, 2000). The four dimensions of PD are detailed below, highlighting the ones most frequently cited (and employed) in the literature.

The Strategy dimension of PD can be analyzed from the following perspectives:

- S1. *Management or administration of the portfolio of products (projects)*, joint coordination of current or planned projects, as well as strategic coordination of interproject relations Robertson & Ulrich (1998) and Cusumano & Nobeoka (1998);
- S2. *Evaluation of PD process performance*, evaluation of the PD projects (developed products) in relation to the company's project portfolio (Clark & Fujimoto, 1991);
- S3. *Guidance of the alliances and partnerships for PD*, achievement of inter-organizational integration involving suppliers, customers, institutions, etc. (Cheng, 2000);

S4. *Guidance of interfunctional / interdepartmental relations*, achievement of integration at a strategic level among marketing, engineering and manufacturing (Cheng, 2000).

The Organization dimension of PD can be analyzed from the perspective of:

O1. *Adoption and maintenance of the organizational structure of PD*, involving the choices of functional structure, “light” or “heavy” management, and autonomous team (Clark & Fujimoto, 1991);

O2. *Execution of the work of leadership in PD*, which refers to the skills and behavior of the product manager (Clark & Fujimoto, 1991).

O3. *Execution of group work*, in a culture that encourages communication and conflict management (Cheng, 2000);

O4. *Existence of training and monitoring programs of the qualifications of the people involved in PD*, which increment organizational learning in this process (Rozenfeld, 2000).

Owing to their duality, the Activities / Information comprise a single dimension of PD. This dimension deals with the diverse activities that occur throughout the PD process, and the information exchanged in these activities, with greater or lesser parallelism or simultaneousness. Several authors describe and detail these activities (Clark & Wheelwright, 1992) are two of the ones who do this most thoroughly) and there are also institutional proposals such as the APQP (Advanced Product Quality Planning) model, which is part of the QS 9000 used in the automotive sector. To summarize all these approaches, the following activities are part of this dimension:

A1. *Market research, survey of the technological possibilities and determination of customer requirements;*

A2. *Identification of risks, evaluation of viability and resource planning;*

A3. *Translation of the product concept into style, layout, components and specifications;*

A4. *Supplier involvement;*

A5. *Construction of physical models and evaluation of style and layout;*

A6. *Transformation of the results of the previous stages into drawings and standards;*

A7. *Prototype elaboration, construction and testing;*

A8. *Translation of product design specifications into process design development (manufacturing and assembly);*

A9. *Pilot production and testing for product validation;*

A10. *Execution of stage-gates to evaluate the status of the project;*

A11. *Standardization of the information's content;*

A12. *Standardization of the information's format;*

A13. *Control of information updating and storage.*

The resources used in PD comprise methods, techniques, tools and systems that can be applied to support one or more of the aforementioned dimensions, especially Activities / Information. The following resources can be listed from Clark & Wheelwright (1992), synthesizing several authors, and from Rozenfeld (2000) and Cheng (2000):

R1. *QFD (Quality Function Deployment) method*, to ascertain the customer's needs and desires;

R2. *DFMA (Design for Manufacturing and Assembly) techniques*, design focusing on the company's manufacturing capacity (fabrication and assembly);

R3. *CAD-CAE-CAM and CAPP tools and systems*, which are, respectively, *Computer Aided Design-Engineering-Manufacturing and Computer Aided Process Planning*, used in an integrated or nonintegrated manner to represent the product in drawings, engineering calculations and manufacturing instructions;

R4. *FMEA (Failure Mode Effect Analysis) resources* for product and process (fabrication), *Value Analysis / Engineering*, and *techniques for manufacturing and use of prototypes* (functional and nonfunctional);

R5. *PDM / EDM systems*, which are, respectively, *Product / Engineering Data Management*, integrated or not with the PM (*Project Management*) of the ERP (*Enterprise Resource Planning*) systems;

R6. *IT resources to support group work, seek outside knowledge and for training and teaching;*

R7. *Tools for construction – drawings and maintenance of reference models.*

While this sub-topic focused mainly on PD as a process and on its four dimensions, the next one deals with KM and focused on the approach of knowledge conversions.

2.3. Knowledge management and its conversions

There is a general consensus that knowledge exists in the tacit form (skills and experience inherent to a person, which is difficult to formalize and transfer to another) and in the explicit form (knowledge that is relatively easy to encode into texts, graphs, charts, figures, drawings, diagrams, etc., and transfer to others). The authors that best define and use these forms (Nonaka & Takeuchi, 1995) consider that effective work with knowledge is possible only in environments in which continuous conversion can take place between these two forms, through four knowledge conversion modes, namely:

Socialization – summarizes the conversion of a person's tacit knowledge into another's tacit knowledge, i.e., it is the ‘face-to-face exchange of knowledge between people’. This is achieved through frequent dialogue, brainstorming, work of the “teacher-learner” type, observation and imitation, sharing of experiences, etc.

Externalization – means the conversion of an individual's tacit knowledge into some explicit type of knowledge, i.e., ‘a person's recording of his/her own knowledge’. This is done through verbal or visual reports, metaphors, analogies, texts, images, figures, rules, etc.

Combination – is the conversion of some type of explicit knowledge generated by an individual to add to the explicit knowledge of the organization, i.e., the ‘grouping together of records of knowledge’. This is done by grouping and processing explicit knowledge of various kinds.

Internalization – represents the conversion of some part of the organization’s explicit knowledge into an individual’s tacit knowledge, i.e., ‘personal learning based on checking up on the records of knowledge’. This requires individual reading / viewing and studying of explicit knowledge recorded in different types of documents (texts, images, etc.).

Figure (1) illustrate these four knowledge conversion modes.

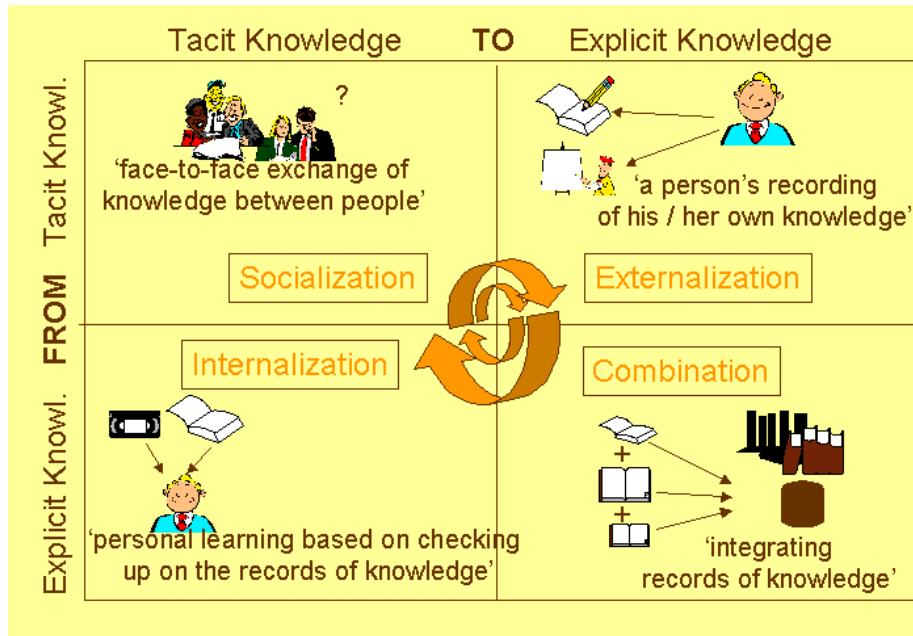


Figure 1. The KM and the four conversions of knowledge.

The discussion of PD and its dimensions and KM and its conversions form the two main axes of the aforementioned model. The next topic briefly describes the methodology employed in the construction and application of the model, whose results are presented in the fourth topic.

3. Methodology

The construction of the evaluation model essentially employs the *hypothetical-deductive method* since, based on Dane (1990), it is based on existing theories about the PD process and about KM to discover answers for a new problem (to understand how the conversions of knowledge occur in the dimensions of this process) and discards, from these theories, those that do not work (refutation) for the solution of the new problem.

The research problem is broached mainly in a *qualitative* and *descriptive* manner, since it aims to describe and interpret the characteristics of a given phenomenon (the correlations existing between the details of the PD dimensions and the conversions of knowledge), defining and delimiting them with the help of a proposed evaluation model.

In terms of research procedure method, the present work uses a *case study*, which allows the PD process to be investigated thoroughly enough to apply the KM evaluation model, checking the hypotheses and best practices used in the construction of this model, without requiring much of the researcher’s or the company staff’s time.

To render the methodological choices for this work operational, the main research instrument used was a *semi-closed questionnaire* applied by means of *structured interviews*. This choice regarding the questionnaire and interviews prevented the interviewees from becoming sidetracked in regard to the analysis of the conversions in the perspectives, activities and resources of the PD dimensions.

This model was tested in a pilot application (Silva & Rozenfeld, 2001a, 2001b) and in a complete case carried out in the PD process of a truck and bus manufacturer, which will be presented herein. In the latter application, interviews were made with ten people from different functions and hierarchical levels involved in the PD process. Basically, these people evaluated the occurrence of knowledge conversions in the dimensions of this process. This occurrence was evaluated both quantitatively, using a Likert scale (varying from 1 – minimum to 5 – maximum, of occurrences of conversions in the dimensions), and qualitatively, based on a judgement of the occurrence of the model’s best practices and hypotheses in the company’s PD process.

4. Case study: testing the model

Table (2) shows the scope of the KM evaluation performed in the PD process of the company of this case study, with the average values for each of the four conversions and for the KM (average of the four conversions) for each of the four dimensions (which represent a set of perspectives, activities or resources) that make up the PD process.

Because of the scope of the quantitative evaluation and of the subsequent evaluation via hypotheses and best practices that will be shown, this article, owing to space limitations, will present only a summary of the aforementioned KM evaluation in PD.

Table 2. Average values for the four conversions of knowledge and for KM in the PD dimensions / process.

PD dimensions	Conversions of Knowledge				KM
	Socializ.	Externaliz.	Combin.	Intern.	
Strategy	4,1 (0,5)	3,4 (0,8)	3,2 (0,9)	2,9 (0,9)	3,4 (0,9)
Organizat.	4,0 (0,7)	3,2 (0,7)	3,3 (0,8)	3,2 (0,9)	3,4 (0,9)
Activities	3,8 (0,7)	3,7 (0,9)	3,6 (0,9)	3,3 (0,8)	3,6 (0,9)
Resources	3,7 (0,8)	3,7 (0,9)	3,3 (1,0)	3,0 (0,9)	3,4 (1,0)
Process	3,8 (0,7)	3,6 (0,9)	3,4 (0,9)	3,1 (0,9)	3,5 (0,9)

Note 1: In each cell: mean (standard deviation)

Note 2: The interviewees evaluated the conversion of knowledge in each of the perspectives, activities and resources of the dimensions of the PD process. Therefore, for each of these details, n is equal to at most 10 (the total number of interviewees).

Despite the limitations imposed by the standard deviation on the comparison of averages, Tab. (2) highlights Socialization as the most frequent form of knowledge conversion in the PD process. As can be seen, the four dimensions of Socialization have a consistently higher final average of occurrence than the average of KM in the respective dimension. Among the four dimensions, there is practically no difference in the occurrence of Socialization, which shows an average consistently equal to or above those of the other three forms of knowledge conversion.

Internalization, in contrast, is in an inverse position, appearing as the least frequently occurring type of knowledge conversion in the PD process, with practically no difference among the four dimensions. Even considering the restrictions involved in comparisons of averages, in the four dimensions, the final average occurrence of Internalization is consistently lower than the average of KM in the respective dimension, and lower than or equal to the averages in the other three knowledge conversions.

An explanation of the basic causes of these positions of Socialization and Internalization, as well as of the presumed intermediary position of the occurrence of Externalization and Combination and the situation of KM in the dimensions and their detailing, requires an analysis based on a different focus than the measurements made through the quantitative evaluation. More relevant for this purpose would be a qualitative evaluation, in which a point by point evaluation is made of the occurrence of the hypotheses and best practices of each perspective, activity and resource of the PD process's dimensions (see explanation of the KM model in Tab. (1)).

Depending on the effective (or not) occurrence of these hypotheses and best practices, one can deduce the occurrence of the respective knowledge conversion, and the reason for its effectiveness or ineffectiveness, enabling one to better explain the causes for the levels of KM in the perspectives, activities and resources of the PD process's dimensions.

Table (3) shows the occurrence of the hypotheses and best practices of the KM evaluation model in the four dimensions of the PD process, according to the evaluation of the interviewer / researcher, summarizing the different statements of the interviewees. The next paragraphs of this topic discuss the results of this table and other outstanding qualitative / descriptive results specific to the perspectives, activities and resources analyzed, which, as mentioned earlier, cannot be presented here in detail owing to the article's space limitations.

Reinforcing what was observed in the quantitative evaluation, Socialization presents the highest percentage of hypotheses and best practices with effective occurrences compared with the other forms of knowledge conversion. Socialization was found to occur more intensively in S2 (Evaluation of PD process performance), S4 (Guidance of interfunctional / interdepartmental relations), O1 (Adoption and maintenance of the organizational structure of PD), O3 (Execution of group work), A1 (Market research, survey of the technological possibilities and determination of customer requirements), A4 (Supplier involvement), A5 (Construction of physical models and evaluation of style and layout), A7 (Prototype elaboration, construction and testing), A9 (Pilot production and testing for product validation), R1 (QFD Method), and R9 (CAD-CAE-CAM and CAPP tools and systems), all showing a mean value equal to or above 4 on the Likert scale and an effective occurrence of practically all their respective hypotheses and best practices.

No occurrence of Socialization of less than the average level on the Likert scale (score 3) was found in any of the four dimensions, and only A11 (Standardization of the information's content) showed a majority of the hypotheses of Socialization with ineffective occurrence.

These findings confirm the perception that the company under study possesses an environment favorable for Socialization, resulting from its actions over recent years to improve communication and "face-to-face" work among the people involve in PD. These actions have permeated the entire process since, as mentioned earlier, there is a

favorable occurrence of the hypotheses and best practices in a variety of perspectives, activities and resources, which are well distributed among the PD's four dimensions.

Table 3. Occurrence of the hypotheses and best practices in the four dimensions of the PD process.

PD dimensions	Conversions of Knowledge			
	Socialization	Externalization	Combination	Internalization
Strategy	9HT 1BP	3HT 2BP	3HT	2 HT
	1HT	6HT	6HT 1BP	8HT 1BP
	91% (10/11)	45% (5/11)	30% (3/10)	18% (2/11)
Organization	11HT 6BP	5HT 4BP	4HT 1BP	8HT 3BP
	1HT	6HT 2BP	4HT 1BP	4HT 1BP
	94% (17/18)	53% (9/17)	50% (5/10)	69% (11/16)
Activities	22HT 2BP	21HT 1BP	17HT	7HT 1BP
	4HT	13HT* 1BP	4HT	14HT
	86% (24/28)	61% (22/36)	81% (17/21)	36% (8/22)
Resources	8HT 3BP	10HT 3BP	3HT 2BP	4HT 3BP
	1HT	9HT*	6HT	9HT
	92% (11/12)	59% (13/22)	45% (5/11)	44% (7/16)
Process	90% (62/69)	57% (49/86)	58% (30/52)	43% (28/65)

Note 1: HT = hypotheses; BP = best practices

Note 2: Blank cell = effective occurrence of the HT and/or BP; Grey cell = ineffective occurrence or lack of information for evaluation

Note 3: The asterisk (*) means that 1 of the HT counted has zero occurrence

Note 4: Percentage = effective occurrence of the HT and BP in relation to the total HTs and BPs in the cells

Externalization holds an intermediary position of occurrence in the PD process. Analyzing the averages and particularly the percentage of effectively occurring hypotheses and best practices, one can see that this conversion is slightly more present in the Activities / Information and Resources dimensions, likely owing to the needs of documentation and recording required by the actions in these two dimensions.

This is also found due to occurrence of this conversion into A2 (Identification of risks, evaluation of viability and resource planning), A3 (Translation of the product concept into style, layout, components and specifications), A5 (Construction of physical models and evaluation of style and layout), A9 (Pilot production and testing for product validation), R3 (CAD-CAE-CAM and CAPP tools and systems), and R7 (Tools for construction – drawings and maintenance of reference models), all showing an average value of 4 or more on the Likert scale and displaying an effective occurrence of most of their respective hypotheses and best practices.

However, there are levels of occurrence of Externalization lower than the average (score 3 on the Likert scale) and/or with a larger number of ineffective occurrences of hypotheses and best practices. Such is the case of S4 (Guidance of interfunctional / interdepartmental relations), O2 (Execution of the work of leadership in PD), O4 (Existence of training and monitoring programs of the qualifications of the people involved in PD), and even some activities and resources such as A10 (Execution of stage-gates to evaluate the status of the project), A11 (Standardization of the information's content) and R4 (FMEA resources, Value Analysis / Engineering, and techniques for manufacturing and use of prototypes).

Combination also holds an intermediary position of occurrence in the PD process, as illustrated by the percentage of effectively occurring hypotheses and best practices. This conversion takes place more intensively in the Activities /Information dimension, which is expected owing to the "document agglomerating" aspect of several of the activities. However, there is a certain weakness of this conversion into Strategy, in terms of the percentage of occurrences of the hypotheses and best practices, when compared with the other conversions in this dimension.

This conversion occurs in only two situations with a score equal to or higher than 4 (and with all their respective hypotheses showing effective occurrences), namely in A6 (Transformation of the results of the previous stages into drawings and standards) and in R3 (CAD-CAE-CAM and CAPP tools and systems), which are, respectively, an activity and a resource strongly interrelated and very well structured with the PD of the company of this case study.

The highest number are the occurrences of Combination lower than the average level (score 3 on the Likert scale) and/or with a larger number of ineffective occurrences of hypotheses and best practices. This is the situation of the four strategies, as well as of O4 (Existence of training and monitoring programs of the qualifications of the people involved in PD), only one activity, i.e., A11 (Standardization of the information's content), R2 (DFMA techniques), and R6 (IT resources to support group work, seek outside knowledge and for training and teaching).

As indicated by the analysis of Tab. (2), there are deficiencies in the occurrence of Internalization of the PD process. Although, on the one hand, there is an effective occurrence of hypotheses and best practices in the Organization and Resources dimensions, on the other, the percentage of occurrences is very low in the Activities / Information and Strategy dimensions, which is highly discrepant from the situation displayed by the other knowledge

conversions. The main causes detected for this deficiency are lack of time for reading (study) and the preference for seeking knowledge through contact with other people.

There is no occurrence of Internalization with an average higher than or equal to score 4. In contrast, there are several occurrences lower than average (score 3 on the Likert scale) and/or with a greater number of ineffective occurrences of hypotheses and best practices. All the four strategies are in this situation, as are several activities and resources, to wit, A1 (Market research, survey of the technological possibilities and determination of customer requirements), A2 (Identification of risks, evaluation of viability and resource planning), A10 (Execution of stage-gates to evaluate the status of the project), A11 (Standardization of the information's content), A12 (Standardization of the information's format), A13 (Control of information updating and storage), R2 (DFMA techniques), R4 (FMEA resources, Value Analysis / Engineering, and techniques for manufacturing and use of prototypes) and R5 (PDM / EDM systems).

The average of KM for the entire PD process (3,5) is located between the levels of intermediate occurrence (3) and superior / good occurrence (4), indicating a favorable environment for knowledge conversion and KM. This tendency or evaluation is strongly corroborated by the percentages of hypotheses and best practices showing effective occurrence, most of them close to or above 50 percentage points.

However, there are certain points where KM could be improved, as can be seen from the above analyses, particularly from the standpoint of the different perspectives, activities and resources that are listed as showing a reduced conversion of knowledge (in one or more of the four aforementioned conversions). Before improvements are made in the deficient conversions of these perspectives, activities and resources, however, it is necessary to assess their relevance / importance for the company's PD process. Because this criterion is high, investments in the desired improvements are justified.

Having presented the above analyses based on knowledge conversions / KM, this topic can be concluded by restating these analyses from the standpoint of the dimensions of the PD process:

Strategy, except for Socialization, is the dimension least favorably situated in terms of KM, a fact that is particularly evident from the relatively low percentage of effectively occurring hypotheses and best practices. In this context, therefore, this dimension could be subjected to some improvements to optimize the conversions of Combination and especially of Internalization.

The Activities / Information dimension ranks favorably in three knowledge conversions, but attention should focus on possible improvements in the percentage of effective occurrences of the hypotheses and best practices of Internalization.

The Organization and Resources dimensions are reasonably well situated in terms of KM in the four conversions of knowledge.

5. Final remarks

This case study proved that the proposed model achieved its purposes. It presented no problems of understanding and application, and generated desirable results in the identification of gaps to be optimized in the occurrence of certain knowledge conversions into some details of the dimensions of the PD process.

The case study allowed for a comprehensive and complex application of the model, contributing to prove its viability in evaluating KM in PD. No deficiency was found in the model's application that could compromise its viability. Examples of this kind of deficiency could be: – difficulties generated by the model in understanding KM in the PD process of the case study; – critical factors or variables about KM in the PD process not foreseen by the model but detected in the case study; and – factors or variables of the model that make no sense or show an abnormal evaluation given the conditions found in the case study analyzed here.

The application of the model also revealed that the evaluation of conversions / KM in the details of the PD process's dimensions is well performed by the combined analysis of two sets of factors: Measurement based on the Likert scale and detection of the occurrence of the hypotheses and best practices. The former makes a generic evaluation of each conversion in the perspectives, activities and resources of the PD dimensions, by means of a perception of quantitative occurrence. The latter specifically evaluates the hypotheses and best practices in each conversion / detailing of the dimensions, by means of a refined analysis of qualitative occurrence. The combination of the two sets means evaluating the same phenomenon (KM in the PD process) from different standpoints, thereby generating a more reliable result.

From the analysis of the conversions in the complete set formed by the PD process it can be seen that, although the ideal theoretical situation is a balance among the four types of conversion, Socialization tends to stand out more than the other conversions. In this specific case, there is a good explanation for this imbalance, i.e., the highly favorable conditions for human relations in PD work that the company of this case study provides.

It would be relevant, in future studies, in the case of companies with less favorable conditions for human relations, to verify whether this tendency for Socialization to stand out would also hold true. If this were found to be so, one could state that Socialization is always the strongest form of knowledge conversion, presumably because of the characteristics of the human intellect, which favors or prioritizes the search for knowledge through direct contact with other people, especially in a creative and innovative process such as PD.

This condition does not imply disregarding the other conversions of knowledge or delegating them to lower levels. Perhaps they may not easily stand out as strongly as Socialization, but they are nonetheless fundamental for the

perpetuation and refinement of the company's PD knowledge, insofar as people need extra effort and wisdom to externalize, combine and internalize them, building up the corporate memory of PD.

Strong Socialization is entirely desirable; however, this type of conversion should not be excessively valued for the exchange of knowledge and experience. If that happened, people would depend too much on sharing knowledge, on others' good will and availability and on individual memory along time, creating unnecessary risks for KM. This case study illustrates this negative situation of dependence in various details of the PD dimensions, inasmuch as the writing and reading of experience, practices and lessons learned are delegated to a much lower level of importance than the search for this knowledge via direct personal contact.

Finally, it is worth mentioning that the results and the analysis of the KM evaluation reveal indications of a direct proportionality between KM and the way in which the PD process has treated its dimensions (Strategy, Organization, Activities / Information, and Resources). Hence, it is advisable for the company's PD to compare the improvements proposed for KM with the trajectory of the PD process, thus enabling it to decide to implement such improvements with a greater certainty of achieving effective results.

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