Organizational learning in the context of product development management

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Abstract: This article discusses the results of research into organizational learning in the new product development (NPD) process, involving three manufacturers. It aims to provide a referential framework to help understand organizational learning in the specific context of NPD, applying this framework to identify practices and methods that promote and facilitate this learning on a regular basis. Based on an exploratory, multiple-case study with a single unit of analysis and qualitative data collected from semi-structured, in-depth interviews, the following methods and practices were found to exert an impact on learning. a) During and post-project learning must focus on the detection and correction of "critical NPD events" so as to improve process performance; b) Both types of learning depend on the nature of the project (derivative, platform, etc.), which suggests the need for a learning strategy specific to each case; c) The stage-gates system can also be used as a formal method to facilitate learning during a specific project; d) Retention and transference (either within or across projects) of explicit knowledge is better addressed by archival-based mechanisms (documents, reports and FMEAs). On the other hand, experience-based methods (face-to-face contact, meetings, project leader) are ideal when knowledge is tacit; e) Leadership style and organizational culture that reward employee commitment and motivation facilitate learning; and f) QFD and FMEA tools help by anticipating and correcting critical NPD events during a project.
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1. Introduction

A series of factors such as fragmented and demanding markets, intense international competition and rapidly changing technologies are causing radical transformations in the way firms organize themselves both internally (operations and management systems, product development, performance measurement system) and externally (alliances, acquisitions, merger, supply chain networks) (FLEURY, 1999; CLARK & WHEELWRIGHT, 1993).

In this context, where innovation plays a major role, the new product development (NPD) process, in particular, has become a source of competitive advantage for a large and increasing number of firms, especially those in more dynamic and competitive markets (BROWN & EISENHARDT, 1995).

According to CLARK & WHEELWRIGHT (1993), NPD success depends on three "competitive imperatives": process speed, efficiency and effectiveness. In order to meet these competitive imperatives they propose the use of a comprehensive development strategy to address the following four main purposes: creating, defining and selecting a set of projects that will provide outstanding products; integrating and coordinating functions and units involved in development activities; managing development efforts as effectively and efficiently as possible and improving development capabilities over time.

This last purpose, the NPD continuous improvement, relies on the firm's ability to solve problems that limit its process performance. NPD continuous improvement is fundamental, if not the only way, to make this process become a competitive advantage in the long run.

There is a body of research linking continuous improvement with the concept of learning (CLARK & WHELLWIGHT, 1993; GARVIN, 1993; LYNN et al., 1996; LYNN, 1998). To continuously improve the NPD process not only is individual learning required, but also organizational learning. The organization has to capture the individuals' and groups' knowledge and learning, institutionalize it, and make it available on a wide, fast and regular basis (CROSSAN et al., 1999).

Organizational learning involves detection and correction of errors (ARGYRIS & SCHÖN, 1974; ARGYRIS, 1976; 1977) and can be divided into the following sub-processes (GARVIN, 1993; ADAMS et al., 1998; SNYDER & DUARTE, 1997; GARVIN, 1998): information and knowledge acquisition, its distribution and utilization, and memory.

Learning is important for the whole company and it is vital for new product development. Complexities of the NPD process such as cross-functional integration and collaboration, changes in customer needs and unreliable market information increase the need for firms to learn while developing products and technologies (LYNN & AKGÜN, 2000).

In the NPD context there are many questions regarding organizational learning. Two of them are discussed in this paper: how can an organization learn from its concrete experiences in individual development projects? Which practices and methods can promote and facilitate this learning?

LYNN & AKGÜN (2000) state that in the last decades organizational learning has been studied under different points of view and various "schools of thoughts" have emerged, each one focusing on a distinct but complementary matter. The aim of this paper is to discuss the main aspects of some theories of organizational learning and apply them to the specific NPD context, building a conceptual model of learning in order to help the understanding of how an organization can learn from individual development projects. Although this question is dealt with the current literature, there is a lack and hence the need of a review that couples the main findings in this area in a comprehensive framework.

Next, this framework is used to evaluate the management of the organizational learning in the NPD process of three Brazilian firms and to survey which practices and methods they use to promote and facilitate organizational learning both during a project and after its end. There are few attempts to do this and they consider either only the post project perspective (CLARK & WHEELWRIGHT, 1993; SNYDER & DUARTE, 1997) or rely on evidence of one industry (THOMKE, 1998; THOMKE & FUJIMOTO, 2000). The methodology used to accomplish this objective was an exploratory, multiple case study with a single unit of analysis and qualitative data, collected from semi-structured, in-depth interviews

The paper is divided into the following sections: firstly, a general view concerning organizational learning will be presented and these concepts are transported to the product development sphere; second, the research methodology will be presented; in the sequence, the cases are described and analyzed; finally, the conclusions will be shown.

2. Model of organizational learning for the NPD process

In this section, the basic concepts of organizational learning are discussed and applied to the specific environment of the NPD process.

To ARGYRIS (1976; 1977), learning (whichever individual, of the group or organizational) can be understood as a process of detection and correction of errors, where an error is any feature of knowledge that makes actions ineffective. When this process enables the organization to adopt new action strategies to reach its objectives, single-loop learning is said to occur. When it is also possible to question the governing values or variables in which actions are based, double-loop learning takes place.

ARGYRIS & SCHÖN (1974) explain that it is a hypothetical-deductive point of view of learning, i.e., learning involves modifications of the theories-in-use based on experience from actions. In other words, organizational learning can be expressed as an interactive relationship between cognition and action: understanding guides action and action informs understanding (CROSSAN et al., 1999).

Another important point to consider is the relationship between the learning of individuals and groups and organizational learning. Not necessarily the former leads to the latter. Organizational learning consists of the sum of individuals' learning that is shared, developed and refined inside the groups and, finally becomes institutionalized as systems, structures, procedures, routines and strategies (CROSSAN et al., 1999). The underlying logic is that ideas and knowledge happen to individuals not organizations.

Organizational learning is also explained from an information processing perspective (GARVIN, 1993; ADAMS et al., 1998; SNYDER & DUARTE, 1997; GARVIN, 1998), i.e., it involves:

- Acquisition, filtering, interpretation and analysis of information and knowledge;
- Ways to distribute and gather information and knowledge;
- The use of information and knowledge; and
- Methods and techniques to store and retrieve information and knowledge.

Given a broad definition to organizational learning, it is now possible to apply these concepts to the NPD process. Learning from individual development projects is an important and a challenging task to a firm seeking to improve its development capabilities. In relation to learning in this process, that involves various departments and even units and where cause-effect relationships are separated in time and place, an investigation of project outcomes is necessary followed by an analysis that try to find out the root causes of the observed problems (CLARK & WHEELWRIGHT, 1993). Consequently, a planned framework that identifies what can be learned from single projects and sets methods to generate insights and understanding as well as ways to capture them is important.

To sum up, organizational learning in the NPD process can be understood as the identification and correction of errors based on the analysis of the process performance. Learning means firstly discovering what must be changed in the development, secondly taking corrective actions and finally capturing and storing the generated knowledge. Such learning can happen either during a project or after its end.

Situations where things went wrong are raw material for learning, especially those directly connected to development process performance. Such "critical events" must be faced by a firm as a symptom that something should be improved in its development. Table 1 presents five categories of critical events with respective examples and issues for learning.

After identifying a problem, the focus changes to finding out its root causes. However, contrary to individual learning, organizational learning is unlikely to occur naturally, systematic efforts are required. These efforts follow five steps (CLARK & WHEELWRIGHT, 1993):

- Learning must be viewed as a team process to ensure a shared understanding, which is essential to the implementation of new concepts of development;
- The search for problem sources must be guided by a model of how the product development works;
- The analysis of the problems must be based on actual data instead of personal impressions and judgement;
- The analysis must focus on searching for patterns concerning the data collected; and
- The underlying causes of the observed patterns must be pursued.

Framing the problems and a way to uncover them is a necessary, but not sufficient condition for learning. The learning cycle is completed when the organization incorporates insights into behavior, i.e., when it changes the way development is done.

CLARK & WHEELWRIGHT (1993) have identified five areas for obtaining and storing the learning from development projects. Table 2 shows the five areas and provides examples of changes for capturing learning.

Considering the theoretical aspects presented, organizational learning in the NPD process is seen in this paper as consisting of systematic methods for:

- Acquiring, filtering, interpreting and analyzing information about critical events;
- Disseminating and sharing the results of analysis;
- Using it to correct errors and change the way development is carried out; and
- Storing information and generated knowledge.

This model of learning was used to guide data collection and data analysis. With it at hand, it was possible to study methods and practices that promote and facilitate organizational learning in the NPD process. In Figure 1, the main components of the model are depicted.

3. Methods that promote and facilitate organizational learning in the NPD process

This section presents three approaches found in the literature that this study identified as mechanisms connected to learning in the NPD process. They are the proposals of "post-project learning" by CLARK & WHEELWRIGHT (1993) and SNYDER & DUARTE (1997), the "front-loading approach" by THOMKE & FUJIMOTO (2000) and the "stage-gates interval methodology" presented by COOPER & KLEINSCHIMIDT (2001) and ROSENAU (2000).

Table 1. The focus of learning: five categories of critical events in development projects. Source: CLARK & WHEELWRIGHT (1993) p. 737.

Category	Nature of observations	Issues for learning
1. Recurring problems linked to critical performance dimensions	Persistent quality problems with design Engineering changes at pilot for problems that could have been uncovered long before	Does the organization capture solutions and make them permanent? Discipline and methodology in engineering
2. Crucial individual activities/tasks and associated capabilities	Time to complete key tasks Quality of tasks	Do we measure/track the right information about tasks? Do we have the skills needed?
3. Working-level linkages	Timing of downstream involvement Degree of influence exerted by upstream on problem solving in other group	Do we have a process and framework for integration? Do we have the skills, attitudes and values that drive integration?
4. Design-build-test cycles	Speed of the cycle/number of cycles Quality of solutions	Do we have the right people involved in the design-build- test cycles? Do we have the right tools, supporting resources and skills?
5. Processes for making decisions and allocating resources	Time required to decide/number of reiterations Resource constraints	Are the right people involved at the right time with the right information? Do we have too many projects? Do we have an aggregate project plan?

Table 2. Capturing learning from development projects. Source: CLARK & WHEELWRIGHT (1993) p. 745.

Areas of Focus	Types of change to capture learning
Procedures	Changing the specific, detailed sequence of activities or rules that developers follow
Tools/Methods	Teaching engineers and developers new skills in using specific tools ands methods
Process	Changing the broad sequence of activities and phases that structure development
Structure	Changing the formal organization, the locus of responsibility and the geographic location of development activities
Principles	Adding to the set of ideas and values used to guide decisions in development

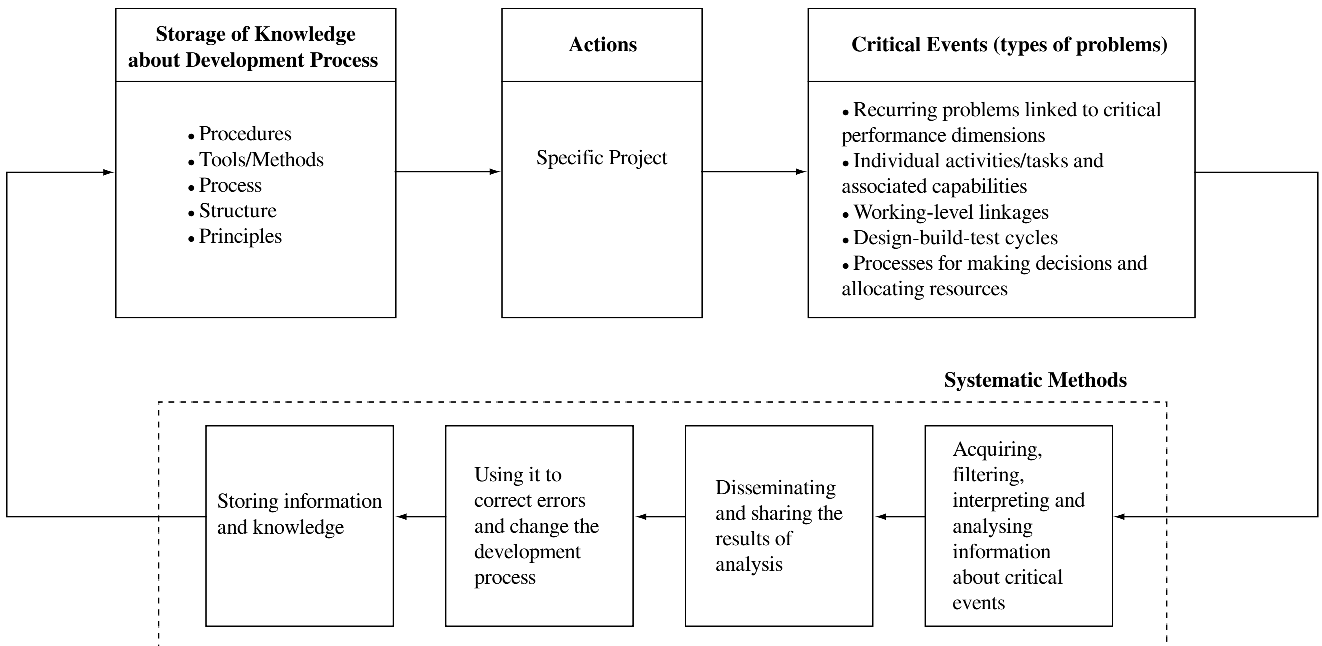

Figure 1. Organizational learning model for the NPD process.

CLARK & WHEELWRIGHT (1993) propose the use of the post-project audit after the end of every project. A cross-functional team would be formed to review the project, not to make sure that development has proceeded according to the established rules, but rather to help the organization learn from the experience. The team would thoroughly review the project identifying critical events and recommending changes that would help to capture the learning that it has developed.

The practice reported by SNYDER & DUARTE has been applied by a global corporation to promote organizational learning in its NPD process on a wide basis. Teams analyze and document critical points of the process, propose improvements and supply a specific department with information. This department has the function to create training programs and other types of interventions designed to help the firm carry out its global strategy. It provides three types of activities:

- Regular training and educational programs for managers and development team members, ranging from a general view of NPD process and factors that contribute to its success to specific techniques as market analysis, technical viability analysis etc;
- An ongoing program attending teams with specific problems; and
- Regular best practice conferences in all units that develop products.

These kinds of improvement efforts aiming at future applications are important but not sufficient. Learning must also be an ongoing activity that occurs during a specific project (ROSENAU, 2000). If the organization learns during a specific project, it is possible to correct errors in the product being developed, improving it or simplifying the remaining steps, allowing a shorter time to market. Besides, post-project appraisals are affected by individuals' memory and availability. In addition, there is a natural incentive to go on to the next project without having time to reflect on the last one.

The stage-gate system can help an organization learn during a specific project (ROSENAU, 2000). In this system, the NPD process is broken into predetermined phases, each one consisting of a series of prescribed, multifunctional, and parallel activities (COOPER & KLEINSCHIMIDT, 2001). Between phases, management evaluates process performance and decides whether the project continues, temporarily stops to correct errors or is cancelled. At these checkpoints, the learning cycle can be triggered.

Another approach found in literature related to NPD learning is the "front-loading problem-solving" (THOMKE & FUJIMOTO, 2000). Here the NPD process is viewed as several interdependent cycles of problem solving. Front-loading means shifting the identification and correction of errors to earlier phases of the product development process. This approach has the potential to advance learning and product performance beyond current levels while cutting development costs and time. With front-loading, learning can be addressed and pushed to the earlier phases of a project.

Front-loading can be achieved in two complementary ways: 1) effective project-to-project knowledge transfer; and 2) rapid problem-solving by optimally combining new technologies (for example, computer simulation) which allows faster problem-solving with traditional technologies (such as physical prototypes), which provide higher fidelity. While the first increases the initial number of problems solved (or avoided), the second one increases the rate in which they can be identified and solved. However, the results of this research are based on a single industry (automotive). Another study (PISANO, 1996) has shown that anticipating problems is relatively easy when practical knowledge is detailed enough to enable the design of experiments and simulation (which is the case of the automotive industry). On the other hand, when practical knowledge is scarce (in emerging sectors, such as biotechnology) many problems can only be solved in actual commercial production or a usage environment. Therefore, the strategy of using low fidelity prototypes (such as simulation) would not work properly.

In addition, as LYNN (1998) claims, knowledge transfer between development teams is not always an interesting strategy. In cases when development projects fall into the "breakthrough" (or radical) type, i.e., they incorporate discontinuous innovations, the team must be free to break with tradition. Thus, the transference of learning between teams is not useful and must be restricted. The author describes some cases where products failed to be real breakthroughs because the team had relied on past knowledge.

4. Research methodology

The methodology used to carry out the research objectives was an exploratory, multiple case study with a single unit of analysis and qualitative data, collected from semi-structured, in-depth interviews. It should be mentioned that as the subject of study is in its initial phase of development, there is the need for a more accurate formulation to support future hypothesis testing, which suggests exploratory research.

YIN (1981) states that a confusion often occurs regarding research strategies (case studies, surveys etc.), types of evidence (qualitative or quantitative data) and data collection methods (observation, interviews etc.). Furthermore, none of the research strategies are linked to a particular type of evidence or data collection methods and vice-versa. Thus, they have to be made explicit during the research design phase.

When the purpose is to explore a situation where there is not a clear and single set of outcomes, the case study design is indicated (YIN, 1981; 1994). In case study research the sample selection has to follow theoretical criteria, inasmuch as random sampling can introduce cases that do not contribute to the subject development. The goal of theoretical sampling is to choose cases to replicate or extend theory (EISENHARDT, 1989).

Firms were chosen from different sectors because of the maximization of the differences between cases makes the control of idiosyncratic sector influences possible. If some similarity is found between cases despite their differences, or if contrasting results can be predicted by some theoretical reason, the analytic generalization can take place. This is the core of the replication logic discussed by YIN (1994). These firms also have a structured and formal NPD process. The unit of analysis is the overall NPD process, thus it is a single unit of analysis.

With regards to the types of evidence, since the present research focuses on capturing people's perspectives and interpretations of their environment, qualitative data were preferred (BRYMAN, 1989).

The data collection technique used was in-depth interviews with NPD professionals. Due to the fact that it is an exploratory case study, a case study protocol was developed and a semi-structured interview was used in order to collect the data. This method is useful because it gives the researcher the flexibility to probe into interesting issues that arise during the course of the interview and, at the same time, standardize the questions being asked to different informants.

In general, the interview concentrated on two big parts. In the first part, questions dealt with the characterization of the NPD process, specifically these areas: portfolio of products; types of development projects (R&D, radical, platform and derivative); phases of the development (concept development, product planning, product/process engineering, pilot production and ramp-up); organization (pre-project, project management, tests and prototypes). This characterization is necessary to compare cases during the data analysis phase.

In the second part, in order to evaluate organizational learning and the methods and practices that promote and facilitate learning, questions were built around the model presented in Figure 1. Informants were instructed to consider both during and post project perspectives.

5. Case description and analysis

The cases presented below were conducted in three well-known and successful firms. They are leaders of their markets and their products are recognized by their quality all over the world.

Data was obtained and tabulated according to the protocol discussed in the previous section. Both within and cross-case data analysis followed the recommendations from EISENHARDT (1989). The first type of analysis involved detailed case study write-ups for each firm. The idea is to become familiar with each case, allowing further comparison between them. In cross-case analysis, data was grouped into categories and similarities and differences between cases were pursued.

5.1. Case A

Firm A is one of the three Brazilian units of a multinational company, which was founded in Germany in 1761. It has been operating in Brazil since 1930 and its products include pens, pencils, colored-pencils and cosmetic pens.

Its NPD process is formal and well documented and fulfills ISO-9001 standards. Even though firm A works with all types of projects aforementioned, about 2/3 of its new products are derivatives. Therefore, it uses a functional approach to project management. Moreover, all the development phases, from concept to ramp-up, are led by the unit itself.

Although the unit uses a system of phases that is largely functional in focus and operation, it has introduced mechanisms to achieve integration. The development process is managed by two coordinators (from technical and commercial areas) and a project office. Both are committed to its success. Coordinators meet functional managers regularly (once or twice a month), follow NPD performance and manage cross-functional conflicts. In addition, between development phases (called "filters"), coordinators and functional managers analyze process performance against the criteria elapsed time, costs and quality of tasks.

During a specific project, problem-related information is acquired in two ways. First, in an informal fashion, employees report problems to coordinators and functional managers. Then, coordinators and functional managers analyze this information in meetings. The intention is to obtain a better solution to the problems and facilitate the dissemination of the results to the functional areas.

The second way, more formal than the first one, used to detect and correct errors is the milestones between project phases (the filters). As these checkpoints are used to verify and validate the project to the next phase, they are also used to detect, discuss and solve problems. When no consensus is reached the project office gives the final word.

After problems are detected and plans to resolve them are set, coordinators are responsible for implementing and checking corrective actions. On these occasions, the scope of the corrective actions is the project only. The firm also tries to anticipate and avoid errors using some tools such as FMEA, QFD and Value Analysis/Engineering. The criteria costs and time spent are used to evaluate the results of corrective actions.

Post-project learning is stimulated by the following mechanism: during pilot production and ramp-up, customers and partners' inputs are used to acquire information concerning problems in the product. This information is reported, both informally and formally (documents), to coordinators and functional managers. At the end of the year, there are meetings that involve the NPD professionals from the unit. This data is then analyzed and work procedures are revised, aiming at improving the development process. The project office is responsible for changing the firm's NPD process.

The generated knowledge (both during and post project) is stored and transferred to future NPD teams in two ways:

- Detailed documents containing specific problems and respective solutions are kept in a archive; after three years documents are sent to a central file; and
- Face-to-face contact between individuals in an informal fashion, as well as in a formal one, through internal meetings and annual conferences between the three Brazilian units.

According to the interviewee, the first method is ideal for easily encoded knowledge, while the other one deals with tacit knowledge.

It was also reported that the style of leadership adopted (centered on the employees' commitment and motivation rather than on hierarchical authority) facilitates both the transference of knowledge on an interpersonal basis and the learning of individuals. In the informant's point of view, it is easier for individuals to assume, understand, and learn by their own mistakes when the organization has a culture of not punishing before knowing the real reasons underlying the faults.

Nevertheless, we felt the lack of a better structured routine to cope with information retrieval and use from past projects. It only depends on the project's participants. Besides, during a project, only these individuals learn and the NPD process is revised at the end of the year, not at the end of the projects.

Finally, a question about the main problems in the development process was asked. The answer was: problems in product quality, resource constraint, delays in the project and higher costs. The informant was then instructed to relate these observations to the categories of critical events in Table 2. The interviewee reported that all the five theoretical categories had happened and were closely related to his initial answer. The interviewee also informed us that the coordinators acting as gatekeepers inside a functional-oriented development process were very effective in managing the critical event "working-level linkages".

5.2. Case B

Firm B is one of the Brazilian units of a multinational company. It was founded in 1979 in the city of São Paulo and works in energy transmission and distribution. Internally the plant is divided into the areas of low, medium and high voltage. The high voltage area assembles circuit-breakers (between 72.5 and 525 KV) and can be classified as a job shop.

Its product development process consists of customizing and adapting basic technology developed by its headquarters in Berlin to the specific local context, which includes: nationalization of components and adaptation of the product to each customer requirement. As a result, project management organization is functional. The only department that is allocated full-time to projects is the technical department, which has 32 employees and where the interviews took place.

The project starts when the client (other firms and energy concessionaires) contacts the sales department. A viability study is made and a pre-project is sent to the client. A contract is signed and then the pre-project is detailed and sent to the production and assembling department.

Product quality is the main competitive imperative of the development process and in order to fulfill the company's rigid quality standards, the unit relies extensively on tests. The department of quality control has the ISO 9001 and 14000 certificates and run the following four types of routine tests, which are standardized and documented in technical reports kept in files.

- Inspection of component batches received from suppliers. They are implementing the concept of "supplier chain management" to improve this area;
- Tests to measure the conformance of components produced and assembled in the factory;
- Functionality tests in all products inside the factory; and
- Functionality tests in all products assembled at the client's site.

Due to the high specificity level of the projects, the main type of problem that can arise is related to product functionality – it does not work properly (not according to specifications). This problem could be intimately linked to the critical event "problems in the build-design-test cycle". Other problems reported that delay projects and make their costs higher were:

- Problems in decision making and resource allocation (critical event from Table 2 as well);
- Client requires changes in the product specifications during a project;
- Client requires product specifications not according to standards; and
- Project scope ill-defined.

With regards to product functionality problems, during a project they are discovered by the aforementioned tests. 100% of components and assembled products are tested. Tests are very effective, being able to discover more than 90% of functionality problems. Quality department and engineers are responsible for analyzing and correcting the errors. Additionally, the former is responsible for implementing and checking corrective acts. The quality of these corrective acts is evaluated by the final product nominal specifications and tolerances.

After the end of a project, clients inform the technical assistance department of any problems. Due to product characteristics, maintenance and technical assistance is provided to clients by this department. These complaints are reported to the quality control and technical departments. The first is responsible for their analysis while the second for their correction.

Information regarding problems is shared in two ways. The first is formal and consists of the documented tests. These documents are very detailed and standardized, containing data of the tests, a description of the faults and the solutions found. Furthermore, project drawings are stored in computer files (AutoCAD) and depict all modifications made throughout the project. Both documents and drawings are easily retrieved during and after a project.

The second and most important way to share information is on an informal basis. The high voltage area relies heavily on this approach. There is an intense contact between team members and between management, engineers and production areas because the high voltage area has few employees. Team members and project managers are located in the same place and the area of tests is next to their building. Employees are constantly sent to the headquarters in Berlin to receive technical training.

However, it was noticed that the scope of the corrective actions was limited to the project, that is, the learning experienced by individuals and the team is not converted to systematic procedures, routines or structures. In addition, information retrieval and use from documents or drawings only depends on the project's participants. In relation to this question, the informant highlighted that it is very difficult for an improvement in a project to be shared with others because each project is very specific. It also seemed to us that they were more concerned about team's learning during a project than post-project learning, inasmuch as the detection and correction of errors are reactive (customer complaints).

5.3. Case C

Firm C is one of the three Brazilian units of this multinational whose head office is located in Berlin, Germany. It operates in the market of vehicles (buses and trucks), was founded in Brazil in 1959 and has about 9,500 employees nowadays. The unit is also the company's centre of excellence in medium and large truck projects. In average, it assembles 135 trucks and 30 buses daily.

Its NPD process is formal and documented and follows the requirements of ISO 9000 and VDA 6.4 norms. All of the NPD phases, from concept to ramp-up, are made inside the unit. Additionally, the unit develops four project types (derivative: 5%, platform: 60%, radical and R&D: 35%).

Due to the fact that most project types are platforms, the unit uses a matrix structure for its project management and leadership. To obtain integration during product planning, the QFD tool is used. Moreover, the project leader is responsible for integrating functions and circulating knowledge between team members. The interviewee highlighted that this individual is extremely important for development success. "**…without him** (the project leader) **integration is very difficult because the firm is big. Its duty is more to integrate and keep team members updated than ruling. Fifty percent of project success depends on him…**".

Tests and prototypes are extensively used during a project. There is a specific area to develop and deal with suppliers and another to take care of prototypes, which are tested for functioning, assembling and durability. During development, problems with the product are discovered through the tests, which are very efficient as they can detect 95% of problems before ramp-up.

There also is an orientation to prevent and anticipate problems. In this case, two tools are particularly important: QFD and FMEA. QFD minimizes the problems of integration between functions and facilitates the generation of a product concept which is easier to be implemented, avoiding downstream problems with crucial tasks, speeding up project execution. With FMEA, it is possible to anticipate quality problems in the product. It is also used as a formal and structured way to share knowledge between projects. This tool allows for past errors and specific solutions to be checked in order not to occur again. It is a common practice for teams to verify FMEAs from past projects in search of useful information.

The analysis of this data is carried out in meetings between the project leader – which is responsible for its dissemination and the monitoring of the corrective actions – and the functional managers – which are responsible for implementing these corrective actions. Because of the norms that are adopted, alterations in the project are well documented in reports and drawings and both are saved on an electronic database.

According to the informant, there is usually an attempt to detect and solve problems during the projects. The meetings between the project leader and the functional managers act as a moment for them to try to discover the root causes of the errors. However, we felt that a lack of a routine to link individual and team learning to formal changes in the development process.

After a specific project ends, detection and correction of errors are circumscribed to the product, not reaching the process as a whole. Problems felt by customers are reported to technical assistance and engineers provide their solutions. Modifications in any subpart of the product are signed in the drawings and reports (kept in archives as commented above). The procedure is quite similar to that described during a project.

We perceived that most of the focus of the formal systems and procedures to anticipate and detect errors, respectively FMEA and tests and prototypes, are oriented to the product only, except for the QFD, which can handle two of the critical events presented in Table 2. Detection and correction of other types of critical events depends entirely on the team. In these cases, learning does not spread beyond team's frontiers. When asked about the critical events of Table 2, the informant acknowledged that all of them had occurred.

5.4. Case analysis

In this section, the variables described for each case were grouped in tables and then compared regarding their similarities and differences. Tables contain the characterization of the NPD process for each firm, as well the characterization of organizational learning for the three cases. The result of their analysis is presented afterwards.

Taking into account the case descriptions and Tables 3, 4 and 5, the following can be considered:

1. The dominant type of project in firm B requires a great level of technical expertise, where the primary goal is the quality of engineering solutions. As a result, projects have strong management functional orientation. Therefore, the main type of problem observed (product functionality) derives from

Table 3. A comparison between the variables studied in the firms – NPD process characterization.

		Case A	Case B	Case C
Product line		Pens, pencils, colored pencils and cosmetic pens	High-voltage circuit-breakers	Trucks (main) and buses
Type of dominant project		Derivative	Follow-source	Platform
Phases		From concept to ramp-up	From concept to ramp-up	From concept to ramp-up
Organization	**Generation of alternatives**	Employees and contact with customers	Make-to-order	Market research
	Selection of projects	Marketing studies selling potential	Technical department analysis technical viability	Finance studies economical viability and top management choose by consensus
	Team leadership	Functional	Functional	Matrix
	Team coordination	2 coordinators and a project-office	Functional manager from technical department	Project leader
	Tests and prototypes	Partial and total prototypes	Inspection of component batches received from suppliers; Tests to measure the conformance of components produced and assembled in the factory; Functionality tests in all products inside the factory; and Functionality tests in all products assembled at the client's site.	Inspection of component batches received from suppliers; Tests related to functioning, assembling and durability (component and assembling parts)

Table 4. A comparison between the variables studied in the firms – the characterization of organizational learning during a project.

	Case A	Case B	Case C
Methods to acquire problem-related information	Project milestones Team members report problems to coordinators and functional managers	Tests of functionality	Tests with prototypes
Methods to analyse problem-related information	Frequent meetings between coordinators and functional managers	Meetings between technical and quality control departments	Meetings between project leader and functional managers
Methods to disseminate information	Coordinators and functional managers communicate with employees involved with the project Documents/reports	Face-to-face contact Standardized documents/reports from tests	Project leader Standardized documents/reports
People responsible for implementing corrective actions	Functional manager	Technical department	Functional manager
People responsible for monitoring the results of corrective actions	Coordinators	Technical department	Project leader
Scope of corrective actions	Project	Project	Project
Methods to store information and knowledge	Documents Experience of the involved people	Documents and AutoCAD drawings; and Experience of the involved people	FMEA, AutoCAD drawings and documents Project leaders and experience of the involved people
Methods of transference of information and knowledge between teams	Documents, internal meetings, face-to-face contact between employees; Conference between Brazilian units	Documents and AutoCAD drawings; and Face-to-face contact between employees	FMEA, AutoCAD drawings and documents; Project leaders and experience of the involved people

problems in the design-build-test cycle. We noted that the firm focuses on this critical event due to the quantity of tests performed (component conformance, product functionality both inside the factory and at the client's site). It was also possible to notice that this focus shows good results concerning NPD performance, mainly in terms of product quality, which corroborates with the model adopted in this paper that learning should be centered in detection and correction of critical events;

Table 5. A comparison between the variables studied in the firms – the characterization of post-project learning.

	Case A	Case B	Case C
Methods to acquire problem-related information	Employees during production Customer complaints	Technical assistance	Technical assistance
Methods to analyse problem-related information	Meetings that involve the NPD professionals from the unit at the end of the year	Meetings between technical and quality control departments	Engineering
Methods to disseminate information	Face-to-face contact	Face-to-face contact and documents	Face-to-face contact and documents
People responsible for implementing corrective actions	Project-office	Technical department	Engineering
People responsible for monitoring the results of corrective actions	-	Technical department	Engineering
Scope of corrective actions	NPD process	Project	Project
Methods to store information and knowledge	Documents Experience of the involved people	Documents and AutoCAD drawings; and Experience of the involved people	FMEA, AutoCAD drawings and documents Experience of the involved people
Methods of transference of information and knowledge between teams	Documents, internal meetings, face-to-face contact between employees Conference between Brazilian units	Documents and AutoCAD drawings Face-to-face contact between employees	FMEA, AutoCAD drawings and documents Project leaders and experience of the involved people

2. In relation to critical events, the five theoretical categories from Table 1 had occurred in firms A and C and two of them in firm B. Hence, these categories are a valuable reference to organizations to keep track of critical events in their NPD processes. Firm B has presented more scattering in this variable, and many answers are different from the others, possibly because of the high level of specificity of firm's B projects;
3. Cases A and B were different regarding knowledge transference between projects and the post-project learning. While in firm A there are formal methods for learning after a project, in firm B we could note very little concern of them. A possible explanation might be firm's B types of projects. Seeing that its projects are very specific and have no strong connection, it seems more important to learn during a project. This suggests that the importance of during and post project learning is variable and depends on the type of project which in turn suggests the need for a learning strategy suitable for each case. Furthermore, the facts discussed by LYNN (1998) regarding team's learning strategies should be considered. Since organizational learning depends on team learning, a connection between both strategies is feasible, which helps somewhat to justify the conclusion above;
4. Case A replicates the findings of AOSHIMA (1996) and THOMKE & FUJIMOTO (2000) concerning the mechanisms of knowledge retention and transference between projects, however extends these findings beyond the industry (automotive) in which these studies had been conducted. Data from the interview confirms that the retention and transference of explicit knowledge is better addressed by archival-based mechanisms (documents, reports and FMEAs). On the other hand, experience-based methods (face-to-face contact, meetings, project leader) are ideal when knowledge is tacit. Case A also suggests that the above result is not only valid for retention and transference between projects, but also within projects, which was not part of their work. In addition, case C showed that the FMEA tool can also be used as a mechanism of retention and transference of explicit knowledge across projects and that project leaders are the equivalent to tacit knowledge;
5. Firm A uses a system quite similar to stage gates to manage its projects. This system is appropriate when technical solutions are crucial, but not paramount, and where issues such as the link between technical solutions and market strategy are more important, as is the case of derivatives (CLARK & WHEELWRIGHT, 1993). The checkpoints presented between the phases are a good opportunity to acquire, analyze and disseminate problem-related information, making team learning easy during a project. In firm A, team learning is used to review and improve the NPD process at the end of every

year. The model adopted in this paper considered team learning followed by formal changes in the development process as basic steps for organizational learning. Consequently, the stage-gates system also facilitates organizational learning in the NPD process;

6. The dominant type of project in firm C (platforms) requires a focus on a system solution rather than on any specific technical solution. Likewise case A, integration between functions is crucial, though in firm C integration is more crucial than in firm A. The presence of a project leader (case C) and the coordinators (case A) showed to be effective in managing the critical event "working-level linkages". In firm C, project leaders are responsible for making the knowledge exchange between team members more accessible. It was reported that their power of influence over people depends on their communication and interpersonal ability. In firm A, the adopted leadership style, with emphasis on motivation and commitment, was reported to facilitate knowledge circulation. As team learning is a *sine qua non* for organizational learning, it is possible to hypothesize that leadership and personal styles influence organizational learning in situations when integration is required. Even though dominant projects in case A and C were, respectively, derivatives and platforms, it seems reasonable to suppose that this result could be extended to radical and R&D projects because in these situations integration is more critical and firms normally uses an autonomous team approach; and
7. In section 3, the "front-load" was related to a method to facilitate organizational learning during a project. Evidence found in cases A and C suggests that, apart from the two ways proposed by THOMKE & FUJIMOTO (2000) to achieve anticipation and correction of errors, QFD and FMEA tools could also be used.

In general, the studied firms did not present a formal management of organizational learning in their NPD processes. We could verify most of the variables of the theoretical model, but they were not used in an integrated fashion. The next section outlines some recommendations that could help firms with organizational learning management in the NPD process.

6. Conclusion

The purpose of this paper was to build a model for organizational learning evaluation in the NPD process and find which practices and methods could promote and facilitate this learning on a regular basis. To accomplish these goals organizational learning was considered as consisting of four sub-processes. Therefore, it was possible to note some methods and practices that had impact on each of them. None of the studied organizations were proficient in all of them simultaneously.

In firms B and C, most of the learning from projects is stored tacitly in the individuals involved with the development. Moreover, generated knowledge, either tacit or explicit (archives, drawings, tests reports and FMEAs) is not used to formally change NPD process, but to correct errors in projects only. Thus, we can say that some learning occurs, however it is very limited in scope. Although LYNN et al. (1999, p. 440) claim that in the NPD context "the issue is not how organizations learn, but rather how new product teams learn", we adopted a point of view that considers team learning necessary but not sufficient, that is, even though it is crucial and an excellent way to improve development process, more improvement could be achieved if the process is formally changed and the organization learns as well.

In case A, although there are alterations in the development process at the end of the year and thus post-project learning, we were not able to notice the use of structured methods such as post-project audits. Moreover, most of the learning cycle activities (see Figure 1) do not occur at the end of the project. The combination of these two factors also limits the learning that the firm can take from each project.

These observations suggest that the rate at which one organization learns (or not) is dictated by the most deficient element among those necessary for the learning cycle occurrence. As a result, a potential leverage point is to discover this element and acts on it. The model presented in Figure 1 can be used as a starting point for such a task. The model showed effective in outlining the process of organizational learning in the studied organizations. As their NPD processes were very different from each other, the model seems to be generic and could be used to frame a larger number of firms in different sectors.

One aspect that deserves more research is the critical events, given their importance to NPD performance and improvement. The theoretical categories presented are very comprehensive, though it could be particularly useful to correlate the variable type of project, phases of the project and types of critical events. It is reasonable to hypothesize that different projects at different phases go through different types of critical problems.

Another focus for future investigation could be the identification of a more suitable learning strategy for each type of project. The variable type of project seemed to be the most important for during and post project learning. It could be tested if during and post project learning strategies follow the same pattern of team learn strategies proposed by LYNN (1998).

To conclude, it is important to highlight that organizational learning is a key element in NPD process management because it can ensure its continuous improvement. This study was intended to advance knowledge in this area, providing a framework to help with the understanding of organizational learning phenomena in the specific NPD environment and setting methods to promote and facilitate this learning on a regular basis.

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