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How does PLM enhance international inter organizational new product development?

Knowledge transfer and translation with boundary spanners

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ABSTRACT

An important question for IS researchers and practitioners is how IT can improve new product development (NPD) in the context of inter organizational development. More precisely, this paper aims at understanding how Product Lifecycle Management (PLM) technology contributes to NPD knowledge integration in this environment. It is based on a longitudinal case study of a French industrial Group with design teams located in Europe, which had greatly increased development work with China at the time of the study. The first author participated in PLM implementations in Asia over the course of four years. Data analyses indicate a reduction of communication problems, from which we infer a positive contribution of PLM to knowledge transfer and knowledge translation. PLM reinforces the role of outsourced Chinese engineers who act as a boundary spanner with Chinese suppliers.

Keywords

New Product Development, Product Lifecycle Management, Knowledge integration, inter organizational context.

INTRODUCTION

Historically internal to the firm, New Product Development (NPD) is increasingly taking place across organizations and geographical borders (Boutelier, Gassman et al., 1998; Von Zedtwitz, Gassmann et al., 2004; Van Echtelt, Wynstra et al., 2008). Even within organizations, NPD is complex, necessitating the integration of multiple functional competencies and dynamic capabilities (Pavlou and El Sawy, 2006). While several papers in the Information Systems literature deal with the management of knowledge boundaries in inter organizational development of Information Technologies (Levina and Vaast, 2008), the use of information systems for management of knowledge boundaries in the development of new industrial products has not been fully explored (Nambisan, 2003; Banker, Bardhan et al., 2006). Surprisingly little IS research has been conducted on the effects of IT in NPD projects (Argyres, 1999; Nambisan, 2003; Pavlou and El Sawy, 2006; Boland, Lyytinen, Yoo); it is rather NPD research which has focused in the way they manage knowledge integration (Sethi, Pant et al., 2003; Song, Berends et al., 2007). Existing papers do not focus on detailed mechanisms for managing knowledge across inter organizational boundaries through information systems and do not analyse NPD processes over significant periods of time. Because such projects transpire over long periods of time, the most appropriate approach for understanding this phenomenon is a longitudinal one. Such an approach enables us to infer the causal mechanisms underlying the findings of previous researchers who have taken a cross-sectional approach to understanding NPD (Banker, Bardhan et al., 2006; Pavlou and El Sawy, 2006). We therefore contribute to the literature by conducting a longitudinal case study of the effects of IT on knowledge integration in an inter-organizational and international context of NPD. Our purpose is to understand ways that PLM does or does not support knowledge integration in this context where boundary spanners mediate exchanges between organizations.

When new product development takes place in an international context, knowledge must be exchanged across organizational, geographical, cultural and language barriers. These multiple barriers to knowledge integration create high potential for failure and a consequent degree of risk. This has in turn created demand for IT-based tools to support this complex process and so ensure knowledge integration among actors. Applications such as Product Lifecycle Management (PLM) tools manage product information and data using object storage and workflows, which support a structured framework for collaborative engineering based on milestones and predefined key tasks (Grieves.; Merminod et al.; Nambisan).. These tools support the definition and standardisation of workflows and information objects as they are produced and used during the design process (Batenburg, Helms et al., 2004). Also referred to as collaborative product commerce (CPC) tools (Banker, Bardhan and Asdemir, 2006; Welty and Becerra-Fernandez, 2001), they are designed to integrate knowledge and information across functional boundaries as they are used by multiple actors in various different functions, supporting the development phase from design to industrialization. It is important to point out that PLM has little to do with creative and ill-defined research activities and processes, rather mainly supporting development tasks.

THEORETICAL BACKGROUND

Our theoretical framework is first placed in context of international and inter-organizational NPD. We then present a knowledge integration framework through knowledge transfer and translation (Carlile, 2004) and develop some propositions related to the contribution of PLM.

International and inter-organizational NPD contexts

NPD process are becoming geographically dispersed, and so are increasingly performed in inter-organizational situations in order to leverage complementary resources (Boutelier, Gassman et al., 1998; Nambisan, 2003). NPD crosses national and organizational borders as well. The role of information and communication technologies in the development process is one of the six major challenges in managing global R&D (Von Zedtwitz, et al., 2004). Despite early application of the information processing view of the firm in studies of R&D phenomena (Allen, 1984), the strategy and innovation literatures generally emphasize communication capabilities measuring communication frequencies and patterns based on face to face, telephone and emails (Nambisan, 2003; Von Zedtwitz, Gassmann et al., 2004; Subramaniam, 2006). Some researchers have looked to videoconferencing and documentation access (Moenaert, Caeldries et al., 2000) as means of improving the communication infrastructure, but this work is based on generalized descriptions of media use and does not consider the conceptual and theoretical processing properties of the information systems used. In the case of inter-organizational development, contractual agreements signed before the development phase begins provide a stronger impetus towards convergence than having to adjust *ex post* between different units in the same multinational corporation company. We contend that there is a need to consider the role that communication can play in knowledge integration (or knowledge transfer) when it relies on modern means such as PLM technology. In fact, while stressing the creative tension between face-to-face communication, global explicit knowledge and local tacit knowledge, Von Zedtwitz et al. (2004) recognize that “the amount of explicitly transferable knowledge has tremendously increased” (p.39). Similarly the literature on communication and control modes in the international NPD context does not reflect how PLM is transforming formalization practices (Nobel and Birkinshaw, 1998).

Knowledge integration, transfer and translation

Knowledge integration

NPD requires the integration of knowledge from R&D scientists, engineers and marketers as they work to develop and launch new products (Clark and Fujimoto, 1991). Knowledge integration refers to the integration of individuals’ specialized knowledge (Grant, 1996). Okhuysen and Eisenhardt (2002, p.383) define knowledge integration as the knowledge that is created when several individuals combine their information, having first identified and communicated their uniquely held information (knowledge sharing per se). It is more difficult to integrate knowledge between actors who have different knowledge domains and cognitive schemas than between those who share the same culture and domain knowledge (Okhuysen and Eisenhardt, 2002). Knowledge integration encompasses knowledge transfer, translation and transformation (Carlile, 2004); this paper deals only with knowledge transfer and translation.

Knowledge transfer

According to the information processing view of the firm (Galbraith, 1982), knowledge is external, explicit, codifiable and storable. Knowledge transfer occurs by bridging a syntactic or information processing boundary (Carlile, 2004). The syntactic capacity requires the development of a common lexicon for transferring domain specific knowledge. Transfer is based on organizational routines with minor evolutions where knowledge sharing is quite easy. This perspective is the primary basis for technological approaches to knowledge integration which emphasize storage and extraction mechanisms (Davenport, 2005). PLM tools are based on a common database and therefore enable unicity of data. A common knowledge repository between actors increases their level of interdependence and the level of information transparency according to conferred access rights. Transfer constraints correspond to basic problems of knowledge circulation and information access among project members.

For us, the challenge of knowledge transfer is to ensure mechanisms of knowledge coordination and common knowledge. Coordination requires understanding the distribution of expertises (Malone, Crowston et al., 1999) whereas common knowledge relies on the management of interactions between actors with different knowledge repositories who aim to create a common objective (Hoopes and Postrel, 1999). Managing common knowledge is difficult in inter organizational development because of differences in organizational and functional expertises due to actors' specialisations such that they belong to different cognitive environments (Hoopes and Postrel, 1999; Carlile, 2004). The definition of a common lexicon between these actors becomes crucial. Knowledge coordination problems create knowledge transfer issues since they are linked to the difficulty of identifying and synchronizing individuals or groups for diagnosing or solving specific problems that necessitate knowledge exchange (Reich and Benbasat, 1996).

The interorganizational environment forces firms to codify and define a minimal process for supporting NPD. PLM systems should enable knowledge transfer improvements due to their storage and retrieval functionalities. In inter organizational NPD work, heterogeneous and diversified actors produce and communicate information artifacts which can be viewed as boundary objects (BO) (Star and Griesemer, 1989). BO are objects, documents or other artifacts created and used during collaborative development, such as schedules, specifications or 3D models. In inter organizational knowledge transfer situations, knowledge codification and transparency of the communication network are essential for ensuring the effectiveness and efficiency of communication among the project team (Moenaert, Caeldries et al., 2000). The implementation of PLM plays a key role in reengineering knowledge codification and offers a virtual platform for codifying and sharing all project and product explicit knowledge.

Proposition 1: PLM facilitates knowledge transfer in international Inter Organizational NPD through increased transparency and codification.

Knowledge translation

Knowledge translation is a more complex type of knowledge integration. This second perspective incorporates cultural aspects of integration (Adams, Day et al., 1998; Kellogg, Orlikowski et al., 2006) and relies on conventions between specialized actors with a common knowledge repository. A common lexicon and transfer rules are not enough. Knowledge translation has a more tacit, situated and experiential component. The complexity of translating knowledge comes from the need to bridge semantic or interpretive boundaries. This type of knowledge integration depends on the development of routines to facilitate actors' adaptation (Sambamurthy, Bharadwaj et al., 2003), and is supported by common language definitions and experiences (Wenger, Roy et al., 1999). Knowledge translation involves sharing evolving objects that are minimally codified (Carlile, 2002), and a semantic capacity for developing common meanings and identifying novel differences and dependencies.

Due to its nature, knowledge integration is hard to measure (Grant, 1996) and this is especially true of knowledge translation. A good approach for analyzing the contribution of PLM to knowledge translation is to measure the reduction of errors that occur during the NPD process. A glitch is a gap in shared knowledge, an unsatisfactory outcome during a multi-agent project that is directly caused or allowed by a lack of cross-functional or inter-specialty knowledge about problem constraints (Hoopes and Postrel, 1999). Glitches can be avoided if actors have common knowledge and can understand and interpret differences in knowledge representation (Hoopes and Postrel, 1999). Improvement in knowledge translation is correlated with a decrease in the number of errors in communication between actors. We prefer to qualify these critical errors directly related to bad knowledge interpretation on projects as translation problems.

In order to reduce translation problems in Inter Organizational NPD, mediation is critical. Some actors play a key mediating role in order to ensure knowledge translation between intra and inter organizational actors. The literature on knowledge

management has emphasized the importance of relying on individuals to perform boundary spanning roles (Pawlowski and Robey, 2004; Levina and Vaast, 2005). Boundary spanners are vital individuals who facilitate the sharing of expertise by linking two or more groups of people separated by location, hierarchy or function (Levina and Vaast, 2005). Typically, boundary spanners play several roles in everyday relationships in NPD projects: they (1) bridge lexicon gaps, (2) reconcile interpretive differences by creating shared meanings, and (3) facilitate means through which individuals can jointly transform their local knowledge. In order to analyze their operational role, Levina and Vaast distinguish between nominated boundary spanners and boundary spanners in practice. Thus, boundary spanners in practice build a new joint field between two fields, whereas nominated BS mainly play an institutional role. In inter organizational NPD, it is essential to analyze boundary spanners in practice because those actors transform tacit knowledge into explicit knowledge (Pawlowski and Robey, 2004). This is especially important in cross national NPD collaboration because there are problems caused by differences in expertise interpretation and national cultures which increase the complexity of project collaboration. In this context, PLM facilitates BO exchanges used by boundary spanners to manage operational semantic boundaries and ensuing problems of interpretation.

Proposition 2: PLM enhances knowledge translation in international inter-organizational NPD with the help of Boundary spanners

Figure 1 below presents the conceptual model underlying the 2 propositions developed above.

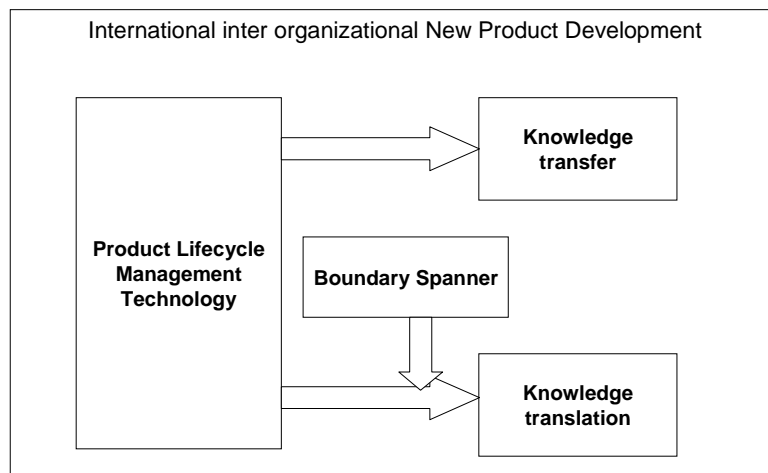


Figure 1. Conceptual model

RESEARCH SITE, PLM TECHNOLOGY, AND METHODOLOGY

In order to fully understand the context and the social and political interactions between actors and technology, the design of this research is grounded in a longitudinal real-time approach (Eisenhardt and Graebner, 2007). Real-time cases use longitudinal data collection of interviews and observations, both of which help to mitigate retrospective sense-making and impression management.

Research site and context:

The case is sited in a French industrial Group that develops small domestic appliances with international brands (€2,8bn turnover). The external environment of this Group is characterized by strong competition, pressure from large retailers and important changes in consumer behavior that have occurred since 2000. In order to manage this R&D situation of international adaptation (Nobel and Birkinshaw, 1998), a growing number of products are developed with Chinese suppliers: 40% of finished products were co-developed with the Chinese in 2007, up from less than 10 % in 2000. IONPD is organized around a three group structure. The first encompasses European project teams which are organized into groups of around eight to ten actors with specialties such as marketing, styling, technical staff, quality, standards, and logistics. The second group of actors associated with the Group’s development efforts is based in China and provides trading and development support. There, workers are tasked with identifying suppliers, participating in new product development and supporting

logistic, quality and administrative responsibilities. The outsourcing engineer is in charge of following projects from the supplier's side. Suppliers make up the third group of actors in the IONPD process.

Data collection

In this research, we use several techniques in order to obtain data saturation using different sources of data and information. The observation process was organized around three main phases: diagnosis before PLM implementation, the reorganization and implementation process, and post implementation. Data collection consisted of a combination of interviews, project documentation, observation and basic statistics from PLM and previous IT solutions (Table 1). Interviews were conducted with actors of various profiles such as marketing, styling, engineering, quality, standards. There were no restrictions on access to documentation, so we were able to collect all emails, specifications, presentations and key exchanges on the project. We also used statistics from the PLM application in order to better understand how it was used.

DATA COLLECTION	Phase of longitudinal analysis		
	Before PLM	During PLM implementation	Post implementation
<i>Collective interviews</i>	6	5	7
<i>Individual non recorded</i>	22	31	25
<i>Individual recorded</i>	N/A	N/A	10
<i>Secondary data</i>	All documents concerning analysis phase: mails, specifications...	Documents such as implementation rules, procedures	Documents such as project communication, trainings...
<i>Field notes, actions Researcher presence 3 days per week</i>	Daily field notes based on observations during diagnostic phase: needs analysis.	Field notes and participation to choices in implementation rules in PLM Perform trainings (as PLM trainer) in Europe and China	Field notes concerning post implementation support
<i>Artefacts</i>	Statistics based on legacy IT solutions on projects, BO...	N/A	Statistics from PLM: number of users, number of objects per project.....
<i>Period</i>	6 months From September 2005 to February 2006	6 months From March 2006 to August 2006	12 months From September 2006 to August 2007

Table 1. Data collection

Data analysis

We combined ethnography with descriptive and axial coding (Huberman and Miles, 2002). This analysis enabled us to better understand the nature of knowledge integration and the specific mechanisms of knowledge transfer and translation. The level of coding we used was the sentence. The data analysis was conducted using NVivo 7. Coding of knowledge transfer and translation enabled us to identify sequences and patterns of how knowledge integration was actually implemented in the inter-organizational NPD process studied. A second coding of data was performed by an external researcher in order to ensure reliability of results. We mixed elements collected in interviews with basic statistics from projects and from the PLM system. To see how PLM contributes to knowledge transfer and translation, we identified differences before and after PLM installation. After the PLM launch, we analyzed the operational uses of PLM and its role in problem sharing and coordination and error reduction.

In order to perform the analysis and analyze the contribution of PLM to knowledge transfer and translation, we have precisely defined each construct and operationalized all variables (Table 2).

Knowledge Integration Framework (Carlile, 2004)	Conceptual meaning	Problems addressed
Knowledge Transfer	Knowledge is considered as external, explicit, codifiable and storable Transferring knowledge is transferring codified knowledge	Coordination: The process of sequencing and scheduling activities in product development (Hoopes and Postrel, 1999) Common or shared Knowledge: knowledge held by 2 or more individuals not necessarily communicated to the others (Hoopes and Postrel, 1999)
Knowledge Translation	Semantic and interpretive boundaries Common meanings are developed to assess knowledge at a boundary	Glitch: critical errors directly linked with bad knowledge interpretations on projects (Hoopes and Postrel, 1999) Simple Glitch: * Serial Product Development Process: * Issue slippage: Problems of communication in the case of mutual prescriptions because actors need to take the constraints of other actors into account and cannot. Complex Glitch: Difficulties solving problems among actors due to differences in technical competences and language differences.

Table 2. Operationalization of constructs

RESULTS

PLM enhances Knowledge Transfer through better NPD process structure and increased transparency

Due to the distant locations of actors in the IONPD context, numerous communication problems were reported before PLM implementation. Prior to PLM implementation, most communication occurred through email resulting in very high exchange volumes. Before PLM implementation, some problems were clearly due to knowledge transfer issues. For example, due to the lack of tracked communications, some tasks were performed using incorrect document versions. Many misunderstandings were attributed to outsourcing engineers located in China who had only partial information and knowledge of their projects. Knowledge exchanges between European and Chinese teams were also made difficult when Europeans shared knowledge directly with Chinese suppliers without including the Chinese support team. Coordination problems also plagued the Chinese support team due to the lack of effective project monitoring. Identified problems included simple knowledge transfer due to basic communication errors, and also complex design issues due to a lack of adequate technical competences in Chinese support teams. After PLM implementation, we sought out residual transfer problems in order to distinguish them from those that seem to have been resolved with use of the PLM tool. We distinguish between two types of knowledge transfer problems/ lack of common representation and coordination issues.

Common Knowledge

PLM makes it possible to define and manage common storage rules for project BOs, and to follow the projects with requests and virtual representation. Table 3 describes in greater detail how PLM features contribute to building this common knowledge. Before PLM, only 40% of BOs were stored with clear rules, whereas more than 90% are now clearly stored due to the capabilities of the PLM tool. PLM ensures immediate access to all explicit knowledge thanks to centralisation of project and product information in a single database. PLM ensures minimal codification of BO among actors; this is critical for improving information processes in IONPD projects. After PLM, 30 BOs were codified in order to facilitate interactions and increase understanding between actors. Thus, PLM enabled improved information transparency. For the trading entities, centralized object collection and rules regarding project milestones enabled them to have clear, objective information on the project every day. Before PLM implementation, the trading structure in China made it difficult to obtain an overall view of projects and their progress. After PLM, actors had access to consolidated views from the supplier and other resources. Outsourcing engineers could easily understand the project context since they had access to information on all projects, with secured access to internal PLM resources. Suppliers had access only to part of this information and outsourcing engineers could respond to suppliers' additional requests if necessary. One typical example of BO codification is the Problem Solving List, which was totally altered by the PLM implementation project. Before PLM implementation, this document was

produced manually with collection from all departments: design, quality, standards etc With PLM, predefined common content was defined with a clear focus on information understanding; this facilitated analysis by the Chinese supplier team which in turn had a positive impact on Chinese suppliers who recognized that the new Problem Solving List enabled them to reduce their leadtimes.

Nature	Example of problems identified before PLM	Volume Before PLM	Volume After PLM	PLM features
Minimal codification of Boundary Objects	Errors on products manufactured by chinese suppliers due to the lack of definition of pre requisite informations for project or finished products. Example on finished products due to problems on Technical Sheet	5	40	Definition of templates on key BO. Automatic generation of objects based on stored components. Definition of templates for key boundary objects shared between company and Chinese supplier
Common storage rules for BO	Problems occur because objects exchanged on the project cannot be found due to the use of multiple IT tools and lack of common rules for storing and managing intermediary objects	~ 40%	~ 90%	Common project structure with pre defined localization of objects
BO evolution follow up	Occurs when object evolution is not tracked. A marketing specification is an example: several modifications on preliminary specifications are conducted by marketing but seldom shared with other actors (such as the project leader) or shared without rules	~ 5%	~ 40%	Status and revision information is on all objects
Number of requests for complementary information	Problems in communication of specifications (marketing, technical, quality) between actors situated in Europe and in China. Information is exchanged with some actors but not with all of them	~ 20 requests per project	~ 10 per project	Single database for project and data management Unique project storage and alerts
Virtual representation of BO	Lack of access to some technical information for some actors of the project such as 2D and 3D drawings of the product. This impedes the ability to validate technical options for design quality. This problem arises in the design validation process between the supplier and project leader when CAD tools are different.	very limited	access for all actors	2D and 3D viewer

Table 3. Variation of Common Knowledge problems before and after PLM implementation

Coordination

Using the PLM database, we conducted an analysis comparing the existence of key deliverables on projects and the extent of validation before and after the implementation of PLM (Table 4). We focused this analysis on ten key deliverables (e.g., marketing specifications, quality control specifications, validated bills of materials, etc.). For projects created and managed using PLM, 95% contained these ten key objects, whereas only 75% of the projects managed outside PLM contained these elements. We believe this was due to the fact that all objects collected in the PLM tool were tracked and each key object was electronically validated through workflows. PLM enabled structured storage of project objects and so pushed actors to mindfully respect templates of key objects. It also reinforced the need to respect structured project milestones. After the PLM implementation, 90% of milestone content was validated, whereas prior to PLM, only 20% of milestone content was validated. Workflows serve to reinforce actors’ awareness because validation is tracked and knowledge content is readily available.

Nature	Example of problems identified before PLM	Volume Before PLM	Volume After PLM	PLM features
key deliverables on project	Lack of communication on all project actors about key decisions. An example is a project that is frozen or experiences substantial delays due to geographic dispersion of teams and only use of email	~ 60%	~ 95%	Notification and alerts functionality
Validation of milestones	Difficulties in following relationships with suppliers due to a lack of organized relationships with suppliers: An example is having different interlocutors from the company for the same supplier, which raises problems in operational project follow up Problems in planning management between Europe and China. No common consolidated representations of the project such as milestones and operational tasks Lost time due to poor synchronisation on the level of project advancement. It mainly applies to peripheral actors such as the after sales services (ASS) department, because it is not systematically included in the communication process when these	~ 20%	~ 90%	Validation and diffusion of workflow for important objects
Consolidated view on projects	Lack of a consolidated view on projects raises problems of synchronisation in knowledge sharing. An example is delays in managing planning by the Chinese support team due to the lack of a consolidated view of the project	Limited	Numerous	Automatic dashboards

Table 4. Variation of coordination problems before and after PLM implementation

Proposition 1 is corroborated: PLM facilitates knowledge transfer in international Inter Organizational NPD through increased transparency and codification.

PLM enhances knowledge translation directly through visualization capability and indirectly through boundary spanners

Visualization as key cognitive capacities to solve simple translation problems

During the process of design configuration between the Chinese and French, a cultural difficulty arose from the way project information was presented. Thus, the visualization capabilities of the PLM served to limit translation problems with suppliers and especially with the Chinese. The need to facilitate BO sharing with Chinese suppliers partially relied on the optimization of visualization through objects. Thus, a picture with basic explanations was easier for Chinese suppliers to understand than detailed written technical explanations. With PLM implementation, considerable work was done to rework BO visualization in order to facilitate knowledge translation (Table 5). Thanks to the preliminary work of pre-defining some of the key BOs to be exchanged with the supplier, PLM led to problems reduction. Technical specifications or quality plans were totally re-engineered with the PLM project so as to facilitate visualization. Many pictures and drawings were added in order to facilitate exchanges. Previously, a lot of re-engineering was done on product technical sheets which contained all technical, styling, logistics and standards information on any specific finished product variant. Before PLM implementation, this document was produced manually with component collection from all departments involved; in many cases it was in different formats and information presentation types. With PLM, common group content was defined with a clear focus on information ergonomics such that product colors, technical characteristics, logistics information, and after sales information were produced, and these facilitated analysis by the Chinese supplier design or logistics team. This work had a positive impact on Chinese suppliers who recognized that the new product specification rules enabled them to reduce problems caused by their misunderstanding of the requirements of the French teams.

Nature of translation problem	Example identified before PLM	Average volume of problems on a project		PLM features
		Before PLM	After PLM	
Serial Product Development Process	Before PLM implementation, some tasks and milestones content were partially defined which raised some misunderstandings especially for Chinese suppliers. For example, they had problems understanding anomalies and problems detected by European teams based on prototypes or tests. As quality plan with detailed controls requested was partially defined and not validated by supplier, problems arose.	~ 10	~ 1 to 2	* Codification of BO * Storage rules for BO * Validation process (workflows)
Issue slippage	An example is partial communication on quality requirements to the supplier which creates problems especially during the validation of first manufactured units. In fact, outsourcing engineer had partial information on project and was unable to communicate all contextual information such as the expected real level of quality on the product	~ 10	~ 4	* 3D PLM viewer enables to detect constraints on future product and so enables to solve some errors * Automatic generation of some Boundary Objects content from existing data
Sticky knowledge	Most of the technical resources from Chinese suppliers only have a basic knowledge of English. For occasional suppliers, there is often a language problem combined with lacks of technical competencies. In addition, the local boundary spanner from the company had difficulties to bridge the gap due to its own difficulties to get contextual and complete knowledge on the project. An example is laboratory reports from the company which were too technical and specific to be fully understood by supplier teams.	~ 6	~ 4	* No functionality with basic PLM solutions but web conferences should help to manage those kinds of situations

Table 5. Variation of translation problems before and after PLM implementation

The PLM contributed to the movement from nominated Boundary Spanners to Boundary spanners in practice

The PLM enabled the outsourced engineer, who was co-located or near supplier plants, to be directly connected to the supplier. He was in charge of managing operational relations, answering questions and meeting communication needs. Before PLM, these engineers found it difficult to gather all necessary information on their projects, thus their credibility vis a vis Chinese suppliers was limited.

Before PLM implementation, outsourcing engineers had no CAD drawings to provide a visual representation of the future finished product (Table 5). So, a European project leader was in charge of validating technical options and exchanges with the Chinese supplier to ensure that requests were taken into account. Prior to the PLM implementation, the outsourcing engineer played only the communication role of checking that all information was correctly transferred between distant actors. With PLM, outsourcing engineers have direct access to all project and product available BOs; they can thus easily identify potential semantic gaps between Chinese suppliers and internal information. Moreover, having a 3D viewer is important in their operational relations with the supplier. This functionality enables both sides to share a common visual representation of the future product and easily communicate about potential design problems. The outsourcing engineer plays an operational role by validating options and potentially solving problems directly with the supplier without the intervention of the project leader located in Europe. This boundary spanner earns credibility because he is now able to really manage operational relations with the supplier without intervention from the technical team in Europe.

Our analysis shows that outsourcing engineers play a key role in managing simple translation problems but that they find it difficult to solve sticky situations. This is mainly due to the organization of international NPD in the company investigated. Thus, the Chinese support team aims to help European teams which have technical expertise, rather than nurturing real development skills of those located in China. So, local outsourcing engineers are limited in their ability to manage complex technical problems directly with the Chinese supplier.

Proposition 2 is partially corroborated: Enabled by the PLM tool, boundary spanners play a key role in improving simple knowledge translation but find it difficult to manage sticky knowledge in international Inter Organizational ONPD.

DISCUSSION AND CONCLUSIONS

PLM brings more transparency and enables more confident actions, while at the same time increasing dependence on coordination among actors; This dependence introduced by the technology, called formal intervention (Okhuysen and Eisenhardt, 2002), obviously has positive effects on knowledge transfer. PLM helps to implement this structuring of knowledge flows through boundary objects and allows actors to anticipate constraints and new needs during product development. Formal interventions in the NPD process, such as the use of PLM tools, are essential for improving NPD process through knowledge integration, but sequential process development should be viewed as a first step in the quest to improve the NPD process. Due to the capabilities of PLM, knowledge transfer is greatly increased even between actors who have different national and functional cultures. Knowledge transfer is improved through better coordination and common knowledge. In this study, PLM tools served to facilitate centralization and standardization of key project BOs. The process of contractual IONPD with suppliers can be clearly defined. Coordination is streamlined as the PLM enforces its basis in predefined routines and defined deliverables for each step of the process. Precise key milestones and objects can be defined in a commoditization process (Davenport, 2005) that transforms specific processes into more generic ones such that the integration of new actors is facilitated. In these ways, PLM provided good support for co-development of products in the small domestic appliance sector we studied. A key finding is the various ways that PLM technology can contribute to knowledge transfer.

Before PLM implementation, even though an organizational unit existed in Asia, the boundary spanner role with Chinese suppliers was mainly supported by the project leader, who in the case of the organization studied was often a French Engineer. PLM implementation modified knowledge circulation within NPD teams and led to a reduction of knowledge asymmetry for the Chinese local boundary spanner. These boundary spanners can concentrate their efforts in ensuring knowledge translation with Chinese suppliers around issues concerning language, priority management, technical problem interpretation and conflict prevention (Ancona and Caldwell, 1992; Keller, 2001). Boundary spanners enable reduced communication impedance in projects (Tushman and Katz, 1980). PLM implementation has modified the political and organizational structure by modifying the discretionary power of actors from nominated boundary spanner to practice boundary spanners (Levina and Vaast, 2005).

Our work shows that there is mutual reinforcement between PLM and boundary spanners. Thus, PLM implementation has reinforced Chinese outsourcing engineers vis a vis the supplier and increased their role in project management. Conversely, their use of PLM reinforces its legitimacy for Chinese suppliers. To further this research, a comparison of projects across different companies and implementation conditions might shed additional light on these results.

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