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Facilitating Product Development Knowledge Acquisition: Interaction between the Expert and the Team*

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Product development knowledge cannot be embodied in a specific individual, a specific group of individuals, or a formal process. Those elements can only embody aspects of product development knowledge. Interaction of those elements is what assigns meaning to the aspects of knowledge and allows for their synthesis. Therefore, it can be said that product development knowledge emerges out of the combined interaction of the involved people and resources.

INTRODUCTION

BOTH IN RESEARCH and in industry, it is widely assumed that product development experts possess knowledge that can be transferred to product development teams. However, the specifics of what and how teams can learn from experts are unclear. In order to document what actually takes place when product development experts are brought together with product development teams, expert-team interactions at the vehicle development center of a US automobile producer were studied. The goal was to gain a comprehensive understanding of the content, motives and structure of the interaction, and then to construct a product development knowledge acquisition model based on the findings. Such a model would be grounded in practice and can be used to assess the validity of the assumptions regarding knowledge transfer between experts and teams.

One way of reaching the desired understanding was to consider the demands of the interaction on the experts, and the strategies they employed to meet those demands: what exactly were the experts responsible for, and how did they meet those responsibilities? More importantly, how did the different groups involved in the interaction—experts, teams, organization and researcher—view those responsibilities? In this paper, a conceptual framework for analyzing the similarities and differences between the viewpoints is developed in order to answer those questions. Data is presented in the form of several key observations and select transcripts from structured interviews. Based on the findings, a comprehensive product development knowledge acquisition model is constructed.

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Four conclusions were drawn:

1. Formalized tasks and procedures embodied in a product development process need to be interpreted and contextualized for product development teams.
2. Product development experts can be effective in accomplishing that contextualization.
3. There are two prerequisites for effective expert-team interaction: experts need to be accepted at least as welcomed outsiders—if not as temporary members—to the teams, and the mechanisms experts utilize to facilitate the knowledge acquisition of teams must be meaningful for experts.
4. Knowledge acquisition metrics should be developed before product development processes and experts are deployed so that their impact on product development practice can be assessed accurately.

The findings also indicate that product development knowledge cannot be embodied in a specific individual, a specific group of individuals, or a formal process. Those elements can only embody aspects of product development knowledge. Interaction of those elements is what assigns meaning to the aspects of knowledge and allows for their synthesis; product development knowledge emerges out of the combined interaction of the involved people and resources.

ON THE ASSOCIATION BETWEEN A PRODUCT AND A PROCESS

Prior to discussing the specifics of expert-team interactions at the large US auto producer (referred to as Giant for confidentiality), it is necessary to communicate the context in which the interactions occurred. The main motivation for deploying product development experts (PDEs) within vehicle program teams (VPTs) was to

facilitate the learning of a new product development process (GPDP) by the teams. Therefore, it is appropriate to briefly comment on the relationship between products and product development processes.

Product development *enterprises* inevitably metamorphose into product development *operations* when the organization developing the products, as well the market for the products, grows and the scale of the activity increases. At the enterprise level, the activity is relatively chaotic, thriving on ambiguity and limited structure. Increasing the scale of the activity necessitates an increase in consistency and control, and hence, a higher degree of structure. The enterprise transforms into an operation, and operations run according to processes; products become inseparably associated with processes.

Acting on that premise, what is of interest to this study is how the link between the product and the process can be maintained through the utilization of a process expert. How is the knowledge that presumably resides in a process transferred to, or rather, learned by the people who develop a product associated with that process? More specifically, can experts, who have extensive understanding of a process, indeed facilitate the acquisition of the process knowledge by product developers?

Much has been published regarding product development processes from an engineering perspective [1–3]. However, the published materials tend to be prescriptive—the authors are concerned with advocating specific processes they have developed, and not with how product development processes *evolve* and are *utilized* in practice.

The essential starting point for studying how such processes evolve and are utilized in practice is to realize that—as Bucciarelli and Brereton have pointed out—social interaction shapes the process as well as the product [4, 5]. According to Bucciarelli, the intersection of the individual perspectives of the participants of the product development activity is the determining factor for the process that is being used as well as the resulting artifact. An implication of that argument is that identifying the participants, and their perspectives, of the expert facilitated learning of a product development process would be revealing. This study adopts that approach in forming an analysis framework.

Another prominent view in the field regarding expert-team interactions is to treat experts as intermediaries of a knowledge transaction. Creighton, Jolly and Essoglou have argued that experts act as 'linkers' who form the basis of a transfer mechanism that exists between the source of a body of knowledge (in this case, a product development process) and the utilizer of the knowledge (product development teams) [6–8]. They call the resulting one-way knowledge transfer model, the 'linker model'. However, the underlying assumptions of the linker model are not well grounded, and therefore, are problematic; such models assume the pre-existence of a formulated and transferable *thing* as knowledge. Those assumptions will be critiqued in detail in the Analytical Framework section of this paper.

A more appropriate model is one that Hargadon suggests regarding what he terms 'knowledge brokering' [9, 10]. According to Hargadon, knowledge brokers are free agents—individuals within an organization, or organizations within industry—who establish links between different and disassociated domains of practice and knowledge. They accomplish that by gaining access to the multiple domains, learning the characteristic problems and solutions of each domain, and linking the 'old problems with new solutions and new problems with old solutions by sharing their knowledge within the organization.' In other words, they 'cross-pollinate'. Hargadon's argument is highly relevant to this study since process experts can be viewed as the brokers of product development knowledge. Studying the interactions between experts and teams is crucial to understanding how product development knowledge is brokered. However, Hargadon does not elaborate on *what* is being brokered—defining knowledge in terms of 'problems and solutions' is not satisfactory. This paper will also address that issue directly, and attempt to formulate an understanding of what constitutes product development knowledge.

RESEARCH SETTING

Before introducing the analytical framework, it is necessary to outline the history and goals of GPDP and the PDE function, and the organization of product development teams at Giant.

Giant Product Development Process (GPDP)

The Giant Product Development Process is taken to be the main focus, or rather, content, of the expert-team interaction by the organization. Its learning and application by teams was the main reason for creating the PDE function; PDEs were introduced to the organization as 'process experts' in order to facilitate the deployment and application of it.

GPDP is not innovative in the sense that it embodies groundbreaking product development principles that are new to Giant. On the contrary, it is mostly based on practices that are already in use. However, it is innovative in the sense that it restructures and optimizes the ongoing practices and presents them in a highly methodical form. Therefore, GPDP, as well as the PDE function, can be seen is as inherent components of a restructuring effort.

In the mid-nineties, Giant decided to formalize its product development process. That entailed understanding the way it has been developing

products, documenting that understanding, and optimizing the resulting picture with respect to cost and development cycles time. In order to attain the required understanding, over one hundred managers and technical directors were taken away from their jobs for a month, and were asked to articulate how their groups were getting their jobs done. The reports were synthesized, and the overall structure emerged.

A core process group was formed to populate the structure with any missing details. The process group members had extensive technical and management experience with product development at Giant. They worked for over a year, and produced a process that reflected the existing practices at Giant—a formalization of what was mostly tacit. They improved that structure by removing redundancies, setting more meaningful and functional timelines and deliverables, and coordinating better ways of using resources.

The most pronounced characteristic of the process is its comprehensive scope. Currently, all vehicles being developed at Giant—domestically or internationally—are developed using the same process, and when the sheer size of the organization is taken into account, the implications of such a standardized approach are significant.

Product Development Experts (PDE)

The need for product development experts was identified during the test application of the process when pilot teams experienced difficulties in understanding and applying its principals, and required guidance. It was clear that GPDP would not simply *diffuse* throughout the organization from the core group, and that a more deliberate effort had to be made to train the teams in what it was and how to apply it. Since members of the core group had exclusive knowledge of it at the time, they were the only people who were qualified to act as consultants to the pilot teams. A few of them started doing so, and over time, their interaction with teams proved to be crucial.

The initial confusion experienced by the teams over process issues and the success of the temporary solution of utilizing core group members as consultants led to the forming of an official PDE function. A PDE group, working closely with other process resource groups and teams was formed.

The role requires the experts to have comprehensive knowledge of product development as it is practiced at Giant. Therefore, all of them are recruited from the ranks of experienced employees who have been involved in multiple aspects of product development at Giant as engineers and managers for a minimum of ten years. Four out of the five experts who were subjects in this study had engineering backgrounds and advanced degrees in management. Most of them had been working at Giant for over 20 years, and they all have held at least five different positions.

Vehicle Program Team (VPT)

The vehicle program teams at Giant are platform specific—the people who make up a team have the development of a specific vehicle as their core task. Naturally, teams vary in size and scope as the vehicle program progresses, however, a chief program engineer, a program manager and their staff are permanent members. It is their responsibility to make sure the team has the necessary human and material resources for the program to progress. Typically, an expert is assigned to a team at the start of the program, and remains with it during at least the initial third of the vehicle development cycle. Depending on the needs of the team, an expert can be supporting one to four teams at any given time.

ANALYTICAL FRAMEWORK

The product development knowledge learning that took place between experts and teams at Giant can be modeled at different levels. Similar to Creighton, Jolly and Essoglou's 'linker model' [6–8], a traditional approach would have been to assume that PDEs, the product development experts, were the transfer mechanism for product development knowledge, GPDP, and VPTs, the product developers, acquired it via one-way transfer (Fig. 1).

However, we identified two significant problems with that approach. The first one was that, based on preliminary observations, the process did not seem to be a *thing* that could be passed from one group to another. Even though it could be thought

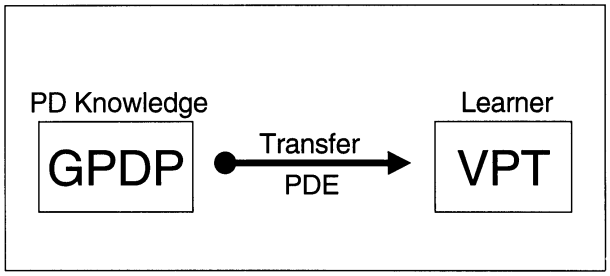

Fig. 1. A traditional product development knowledge acquisition model based on one-way transfer.

to be formally documented in flow charts, resource allocation tables, and task and deliverable definitions, its essence seemed to be the tacit definition of a process—a common informal understanding of a way of doing the things that were necessary to develop a vehicle. Its meaning depended on the interactions of the involved people. Therefore, to assume that process knowledge was being transferred from one party to another during the interaction was too simplistic, and a more comprehensive understanding accounting for the informal as well as the formal aspects of knowledge acquisition was necessary.

The second problem was that even though the organization assumed the main content of the interaction to be the process, preliminary observations suggested otherwise. Judging from their professional backgrounds, experts possessed more 'product development' experience than 'process' experience. More importantly, they seemed to *value* their product development experience *over* their process experience, and acted in the light of that judgement when interacting with the teams. Therefore, it would be more appropriate to call them product development experts rather than process experts, and that distinction has implications for the product development knowledge acquisition model.

In order to develop a more comprehensive model, it was necessary to understand more about the expert-team interaction. Focusing on experts was a good starting point. Even though there were many GPDP learning mechanisms available to teams such as classes and World Wide Web resources, experts were essential components in virtually all process learning that took place within teams by assuming an unusually diverse range of roles.

This finding led us to attempt to define the responsibilities of experts. By determining the nature and boundaries of their responsibilities, we aimed to identify the demands of expert/team interactions on experts. However, that proved to be challenging. The main difficulty with defining the responsibilities of experts was precisely what deemed them interesting in the first place: they got involved in a variety of situations and worked with many team members. That meant that different people at the Giant product development center had different *perceptions* of what experts did, and that there was no one representative view. We saw this as an opportunity, and decided to assess the expert/team interactions by studying the perceptions of the involved parties.

There were four groups with unique viewpoints on expert/team interactions (Fig. 2). The most valuable one was, naturally, the viewpoint of experts—they knew the most about what they needed to do and how they did it. However, their perceptions alone could not be taken to be descriptive of their function; the viewpoints of the organization and teams needed to be considered as well. (We assumed the perspective of the organization to manifest itself in its policies and structures—process-specific and general—including GPDP and PDE role-related documentation, and organizational structures, resources and values.) And finally, the researcher's perspective was considered to be unique and valid as well. It was the only external basis for reflection, and there was no reason to treat the researcher as an objective and non-intrusive narrator.

Our assumption was that documenting and studying the perceptions of these four groups would not only reveal the dynamics of the interaction, but also the mechanisms that enable, or hinder, PD knowledge acquisition. Similarities among the viewpoints might highlight the mutual understandings and unifying elements among the groups, and point at the drives, enablers, and affordances of knowledge acquisition. On the other hand, we assumed that the differences among the viewpoints might highlight unshared understandings and contradictions, and point at hindrances and conflicts.

RESEARCH METHODOLOGY

Three site visits totaling fifteen days over a period of nine months were made. Two methods of data collection were used during the study. The first method relied on ethnography, where the researcher shadowed seven different experts. Observations were documented in the form of field notes and audiotape of meetings and informal interviews. The qualitative insights gained from the initial site visit enabled the development of the analytical framework presented in the previous section.

The other method relied on structured interviews with experts and team members in order to gather the data to be analyzed in light of that framework. The interviews were specifically geared

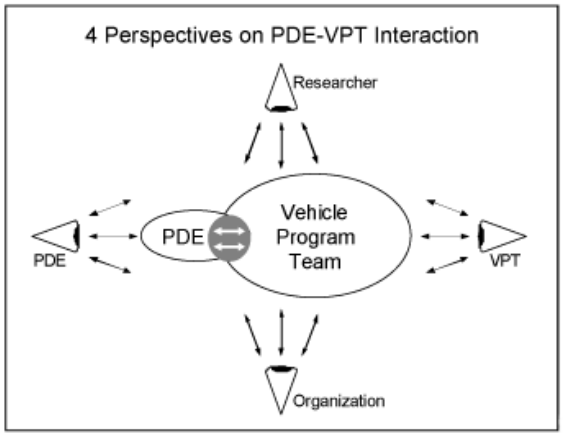

Fig. 2. There were four groups with unique viewpoints on expert-team interactions. Their viewpoints were analyzed in order to understand the actual motives and content of expert/team interactions.

to expose their perspectives on their interactions. Experts were asked a variety of questions regarding their background, work habits, methods, and job interactions, relationship to the process, conceptions of themselves as experts, and conceptions of the PDE job function. Team members were asked questions regarding their interactions with experts, conceptions of the PDE job function, and expert utilization.

The four perspectives and a grounded model

The field notes and structured interview transcripts were analyzed with the above framework in mind. The findings will be presented in two sections. In the first section, the similarities and differences between the viewpoints will be identified. In the second section, those findings will be integrated with higher-level observations, and a comprehensive product development knowledge acquisition model will be constructed.

DISCUSSION OF THE FOUR PERSPECTIVES

In order to compare the perspectives, each group's views on the responsibilities of experts were captured, documented and analyzed. That entailed transcribing the interviews held with experts and team members, collecting the documents created and used by the organization regarding the PDE function, documenting the researcher's field notes, and analyzing them in relationship to each other. Table 1 summarizes the findings, where quotations representative of the four groups' views on responsibilities of experts are presented.

The quotations are thought to be answers to the question, 'Given the extent of your interaction with experts, what do you see as their core set of responsibilities?' After reviewing all of the answers, and identifying the conceptual areas they fall under, nine 'Expert responsibility' categories were created. Answers that are similar in meaning are placed in the same 'Expert responsibility' category. If a group has not expressed a specific view on an expert responsibility, the corresponding cell for that group is left blank. This allows for a visual representation of the similarities and differences between the viewpoints. For example, the answers in the 'Sharing of cross-vehicle program knowledge' category are thought to be strongly associated—the meaning they convey seems to be

Table 1. Views of the four groups on the responsibilities of experts. The quotations are thought to be the answer to the question, 'Given the extent of your interaction with experts, what do you see as their core set of responsibilities?' Answers that are similar in meaning are placed in the same 'Expert responsibility' category.

Expert Responsibility	Expert View	Team View	Organization View	Researcher View
Sharing of Cross-vehicle Program Knowledge	'Reflect Best 'Best Practices in GPDP'	'Bring cross-vehicle program experience to teams'	'Document and share new process experience across teams'	'Broker vehicle development and process knowledge'
Process Reference	'Support teams in the specifics of process deployment'	'Assist teams in the timing of events and deliverables' 'Translate process into reality'	'Answer program specific process application questions'	'Facilitate the implementation of specific process procedures'
Process Training	'Train teams on process methods'		'Ensure that the teams' process training needs are met'	'Train or Facilitate the training of team members on the process'
Risk Management	'Monitor team progress'	'Inform teams of risks due to changes in the timing of events' 'Act as policeman' 'Keep the team out of trouble'		
Gap Filling	'Support necessary team functions'			'Act as wildcard team member'
Process Improvement			'Initiate Process Change Control issues'	'Provide feedback for process improvements'
Gaining Social Acceptance				'Become a welcomed outsider within teams'
Solution Creation			'Develop workarounds when process procedures are not available'	
Tool Utilization			'Coordinate the team's usage of management tools'	

shared among the four groups—whereas the answer given in the 'Solution creation' category is emphasized strongly by the organization only, indicating an unshared meaning.

It is very likely that experts and team members would have provided more than three to five answers each if they were given more time and questioned more thoroughly during the interviews. However, our intent was to capture what came to their mind immediately without having them feel the need to ponder. And when analyzing the documentation and the field notes, our intent was to highlight the points that were articulated well and came across more strongly as opposed to those mentioned in broad terms.

Sharing of cross-vehicle program knowledge

The main expert responsibility the groups expressed similar views on was the sharing of cross-vehicle program knowledge. All four groups perceived experts as interfaces to 'cross-vehicle program experience' and knowledge, or as 'knowledge brokers' within the institution.

The organization, and the experts themselves, were opportunistic in recognizing this need and in understanding how their position within the organization as process experts, which allows them to interact with many program teams simultaneously, could constitute a basic affordance for meeting it. Even though the rationale for the PDE function emerged from the need of creating and sharing process knowledge, its fulfillment extended much beyond that. Because of the organizational allowances and infrastructure-related resources that were necessary to meet that need, the goal—to facilitate the acquisition of process knowledge—constituted a gateway for acquiring product development knowledge in general. The very nature of the PDE function declared experts 'free-agents' within the organization, and perhaps somewhat unintentionally, created the possibility for product development knowledge brokering. More interestingly, all four groups were aware of that taking place. Even though they used different terms such as 'sharing of cross-vehicle experiences', 'best practices' or 'knowledge brokering' to describe it, they were all referring to and acknowledging the same informal learning mechanism.

Process reference

Another expert responsibility the groups expressed similar views on was acting as process reference. All groups recognized that the availability of experts as process references was important to the application of the process. A team member expressed this belief by stating 'translating GPDP into reality' as a key PDE responsibility.

Experts indeed acted like translators, constantly interpreting and contextualizing formal process procedures for teams. Almost all team members who were interviewed lacked process understanding thought their teams. The abstract, formal, and perhaps, even cryptic, nature of the documentation on process tasks and procedures often confused them, causing them to question the meaning behind what they were asked to do. Naturally, team members who lacked prior GPDP experience encountered more difficulty in understanding its procedures, and sought the assistance of experts for clarification.

Experts saw themselves as 'single point answer centers' who tried to answer questions that came up in 'dynamic situations' by providing 'dynamic responses' so that the teams could go on with their jobs with minimum disruption. In one-on-one situations, experts walked team members through tasks or procedures until a clarification was reached. In group situations—mainly during the weekly program steering meetings when all key team members were present—experts answered questions to clarify process issues.

Process training

All groups except teams saw process training as a significant expert responsibility. Even though there was a separate process training group within the organization whose specialty was to prepare and deliver process training classes, experts were expected to monitor the impact of these training programs on teams, and modified existing training schedules when they thought teams lacked the necessary understanding. However, their involvement went far beyond that; they often played a personal role in customizing the classes. In some cases, they took an even more active role by instructing or co-instructing training sessions.

Risk management

This responsibility was well articulated and emphasized by experts and teams, but not by the organization and the researcher. It is plausible that the difference in the level of emphasis resulted from the issue being closely tied to practice; the need to manage risk arises as the program progresses, and in some cases, it is more effective to deal with the need as it comes up rather than to attempt to anticipate and account for it early on.

Teams had already dedicated timing and planning personnel to account for issues that could be anticipated at an earlier stage when there was time to consult with external resources (including experts) and make educated planning decisions. However, when programs were at a more advanced stage, they could not always analyze and predict potential issues because they did not necessarily possess the required breadth and experience—not only in the process but in product development practice in general—to be able to react to situations that developed quickly. Experts did. Their 20+ years of experience in vehicle development allowed them to recognize and draw attention to risks as they were forming. A program manager put this observation into perspective by saying, 'He (the expert) brings cross-vehicle program experience that you don't get within our

team' and he added, 'If I'll be perfectly candid, the knowledge he brings is things I think I should probably have myself, but don't. I don't have that range of experience. He covers my back.'

Experts enjoyed this responsibility because it made them feel the experience they had gained over the years was needed and useful. An expert remarked, 'I'd like to make sure that they have all the things they need or require before taking their next step.' In program steering meetings, when they were not addressed directly, experts monitored the discussion within the group to ensure the team was in compliance with the process. If they felt the team was overlooking a relevant procedure or deliverable, they intervened and clarified its intent and implications so that the team recognized its value and paid more attention to it.

For experts, monitoring teams and contextualizing process and other vehicle development knowledge for them in order to minimize risk was much more than just being an expert; it was an expert put to use. Experts preferred being risk managers to acting as process references since managing risk is proactive, whereas acting as a process reference by answering questions is reactive. Another expert said, 'I get bored with redundancies. I get bored when people treat me as a library function of information.'

Gap filling

An efficient approach to platform-based vehicle development is to structure product development teams so that they vary in size and scope. However, under certain conditions, variability in the composition and nature of the team might also limit its ability to be responsive. Gap filling refers to experts taking initiative in finding and tackling such issues facing teams—process related or not. When filling gaps, experts acted as 'wildcard team members' who waited on the side, and searched for openings developing within teams. It was another way for them to apply their vehicle development experience and feel useful. An expert remarked, 'I go to some meetings and bring some of my prior experience and expertise into the meeting and try to get things moving.' That entailed fulfilling the role of a design engineer, CAD consultant, project planner, manufacturing engineer, etc. An expert explained, 'If there is a hole someplace in the program, if there's something that needs to be done, we just go in and try to help you do it.'

That required experts to take the initiative—meaning teams were not inclined to take advantage of experts as 'reserve' members in this fashion unless they were approached by experts first. There were two reasons for that. The first one was related to the organizational structure. As discussed earlier, experts were, and needed to be, 'free agents' within Giant to meet the diverse range of demands on them. That meant they were not necessarily handed down specific tasks to accomplish. They were conveyed meanings and intents—a broader and qualitative description of what they should accomplish. Therefore, they did not belong to a tight group, and their performance could only be measured indirectly by their manager; PDE managers contacted team managers personally and received feedback on contribution of the experts working under them. Therefore, experts did not directly report to teams. They could not be 'managed' or handed specific 'work' by them. Some experts regarded that as being 'dangerous' because they felt that at times—depending on the stage of the program they were assigned to—they could easily drift into a state where they had nothing to do unless they constantly pursued new responsibilities.

The other reason for the reluctance of teams to take advantage of experts as reserve members is related to the socialization mechanisms between them, which will be discussed in detail under the 'Gaining social acceptance' expert responsibility category.

Process improvement

The process was not static. It was constantly being challenged while teams applied it to product development practice. As an abstract methodology, it contained elements that clashed with reality, with how things actually were and could be. There were parts of the process teams had difficulty understanding. In such cases, experts clarified and interpreted the meaning of the procedure in question for such elements. The basis of those interactions was the elements of the process that required negotiation to gain meaning and value. Newly introduced methodologies are bound to have them. New methodologies are also bound to have elements that simply do not apply, which need to be modified and reintroduced. GPDP contained such elements. An example is a team member objecting strongly to an expert regarding a tolerencing specification dictated by the process. The expert agreed with the objection, and later remarked, 'It (the specification) is an ideal method of doing something that first of all within itself doesn't work, and the program teams don't use it that way. A vehicle surface is not developed that way.'

Experts had the potential of improving the process since they worked with teams, who identified such faulty elements, as well as with the core process group, who maintained the process and could modify them. The organization realized this, and perceived 'initiating process change control issues' as an expert responsibility. That could happen in two settings: during one-on-one discussions with core process group members, and during 'Process Change Control' meetings where several core process members and experts could be present simultaneously. Even though all experts who were interviewed acknowledged these mechanisms, only one was motivated to facilitate process improvements and actually used them. The others believed the influence they could have was not significant in either case.

Gaining social acceptance

Experts interacted with a wide range of personalities within teams, who had different conceptions of them and the process. Some saw experts and the process as resources to be utilized, others saw them as abstractions and as 'policemen'. Some believed they could learn from them, others thought they were complicating their work, and therefore should be ignored. An expert described these differences by saying, 'Every time I go to a different program team, it just blows me away. And I just cannot believe that there's one team that will sit on the edge of their seats and listen to you speak and absorb every word, and other ones every time you open your mouth—because you're a process person—they don't want anything to do with you. The polarity is there.' Such preconceptions regarding the process and experts were not only individual and team dependent; they were also situation dependent. Team members who were receptive in one situation might not be so willing in another.

Experts often referred to the importance of gaining social acceptance from teams by pointing out the danger of remaining an outsider. They believed the most effective position for them was to be a 'welcomed outsider' where they were not necessarily considered a permanent team member, yet were valued and utilized as a knowledgeable resource.

Team members, on the other hand, were aware of some of their preconceptions. Some believed they were biased for a good reason, others were simply cautious and took a wait-and-see approach. PDE managers were also aware of the social barriers, and thought of strategies to overcome them. For example, they urged experts to step in and support teams in any way they can in 'crisis' situations when team resources were stretched and inadequate in order to gain the trust of the teams.

However, none of the groups except the researcher perceived gaining social acceptance as a PDE responsibility. Even though the other groups recognized the importance of the topic, they perceived it as a common *difficulty* encountered by experts in meeting their responsibilities rather than a distinct expert responsibility in itself. The researcher categorized gaining social acceptance as a responsibility because it constituted a prerequisite for realizing any of the other expert responsibilities outlined in Table 1.

Solution creation and tool utilization

Although the organization perceived solution creation and tool utilization as PDE responsibilities, there was not any evidence to point out that the groups perceived them as such, or that they were even performed in practice. Some experts mentioned that they like 'thinking about different ways of doing business' and 'solving teams' problems', but they did not elaborate on how they would achieve those other than through fulfilling the responsibilities already discussed in this section.

INTEGRATING THE FINDINGS: A GROUNDED MODEL

There was a strong consensus on the role experts played in sharing cross-vehicle product development knowledge, providing process information on demand, and assessing process proficiency of teams and organizing training programs when necessary.

As pointed out in the 'Sharing of cross-vehicle program knowledge' category, experts were considered to be free agents within the organization. The implication is that they interacted with several program teams at a time, and therefore, had the opportunity to observe and learn from the application of a variety of product development concepts and the resolution of associated problems. The knowledge they acquired while observing product development situations as an expert, together with the knowledge they had accumulated developing products for over twenty years at Giant, enabled them to interpret and contextualize the formal process knowledge for the teams. Experts had the necessary vision to contemplate the *meanings* behind the process, and to convey them to teams in tangible terms. What teams did with the conveyed meanings was up to them—experts did not interfere with the specifics of their application. Therefore, experts can be thought of as *interpreters*; they relied on the tacit knowledge they had gained while *observing* and participating in product development situations in order to *contextualize* the meaning of formal procedures for teams.

Under the 'Process Reference' category, it was pointed out that experts acted as process reference resources when teams approached them with specific questions. Then, we should ask if the 'Process reference' responsibility is related to the 'sharing of cross-vehicle program knowledge' responsibility discussed above. Perhaps, the question is better stated as: Did experts interpret and contextualize process knowledge when they acted as process references? The answer is mainly no, and that is why a distinction was made between the topics. Experts did not enjoy serving as process references—as 'library functions of information' as one expert put it—precisely because it did not give them the opportunity to interpret and contextualize what they knew. They did not find meaning in relaying content-specific information, which was highly impersonal. Therefore, even though they acted as process references at times, they did not see much value in doing so.

As for the differences between the perspectives, the groups differed in the way they viewed the role experts played in managing risk, filling gaps and gaining social acceptance within teams.

In the case of risk management, experts paid

special attention to the progress of teams by monitoring their decisions, and to the potential impact of those decisions on program deliverables and milestones. Although the organization and the researcher failed to emphasize this as an expert responsibility, experts and teams did not. That was most likely because the organization and the researcher took a theoretical approach, whereas experts and team members—the practitioners—reflected on a behavior that was necessitated by pragmatic needs.

Another expert responsibility necessitated by pragmatic needs, emphasized by the practitioners but not the organization or the researcher, was 'gap filling'. Experts filled gaps within teams when resources were scarce and some tasks were uncovered. They saw those situations not only as opportunities to utilize their subject matter expertise, but also to gain team acceptance as 'welcoming outsiders'. Likewise, PDE managers believed the crisis situations within teams to be excellent opportunities for experts to demonstrate their value in any way they could to earn their trust. In that sense, gap filling helped experts to gain social acceptance from teams.

The researcher thought of gaining social acceptance as a critical requirement for experts to meet any of the other responsibilities. However, experts and the organization did not emphasize its importance as a difficulty rather than a distinct responsibility—they perceived as a difficulty instead. The reason for this difference was unclear, and needs to be studied. However, it was clear that no matter how much 'expertise' an expert might have had, it was difficult for him to be effective and useful in a team without being and feeling welcome. If an expert was not considered a member of the team, any biases of the group toward him and what he was thought to represent—a highly methodical, and somewhat intrusive, process—was bound to influence what the group could learn through him. Therefore, gaining social acceptance from teams was one of the initial challenges experts met when they were assigned to a new program, and had considerable effect on how product development knowledge was acquired.

When these findings are viewed in light of constructing a comprehensive product development knowledge acquisition model, it can be seen that the type of knowledge exchange presented in Fig. 1 is indeed far from being representative of what took place. What becomes clear is that experts did not necessarily possess an inert form of product development knowledge to be transferred, and that, instead, they facilitated the acquisition of *emerging* product development knowledge by interpreting the meanings contained in the process and contextualizing them for teams. It is important to realize that the 'free-agent' status of experts within the organization allowed them to observe a variety of product development practices. That, in return, performed two functions bringing in relevant cross-platform knowledge from other teams who were dealing with similar issues, and constantly grounding experts in practice so that they could develop the vision to bridge the gap between formal process knowledge and informal product development knowledge for teams. Apart from the facilitator/interpreter role, experts also served—at least, had the opportunity of serving—as an interface between teams and the process by feeding the reactions of teams on the process back to the core process group for improvement.

Teams, on the other hand, were primarily involved in applying the product development knowledge they acquired to product development practice. There were two mechanisms for teams to acquire such knowledge: learning from the process principles contextualized for them by experts, and learning from observing their own involvement in product development. The first one concerns their interaction with experts, and the second their involvement in product development practice. Overall, it was difficult to assess how much product development knowledge they acquired through which mechanism. It is plausible to think that the expert interaction is not necessary for them to acquire PD knowledge; instead, it can be thought to augment it. The contribution of the experts was unclear. No metrics were developed by the organization to assess expert effectiveness regarding this, and surprisingly, any other process-related learning mechanism.

And finally, the organization can be thought to be the link between PD practice and PD History: it retained the informal PD knowledge generated during PD practice over time, accumulating a PD history, and reduced it later to a formal product development process, GPDP. The specifics of how it might retain the informal PD knowledge and form a history was not a part of this study, and therefore, was not investigated.

A new product development knowledge acquisition model emerges from these findings (Fig. 3). The model makes a distinction between formal and informal aspects of practice and knowledge. Organization, product development history, and GPDP are seen to be predominantly formal elements, and PDEs, VPTs and product development practice informal elements. The arrows represent the 'acquisition' or 'co-generation' of PD knowledge. PDEs appear at the boundary between formal and informal domains, and play a critical role in transforming the formalized aspects of the process to the informal medium teams prefer to work with. There is no specific node or interaction where PD knowledge is 'created'. Instead, it is thought to emerge from the combined interaction of the represented elements.

CONCLUSIONS

In addition to the product development knowledge acquisition model presented in the previous

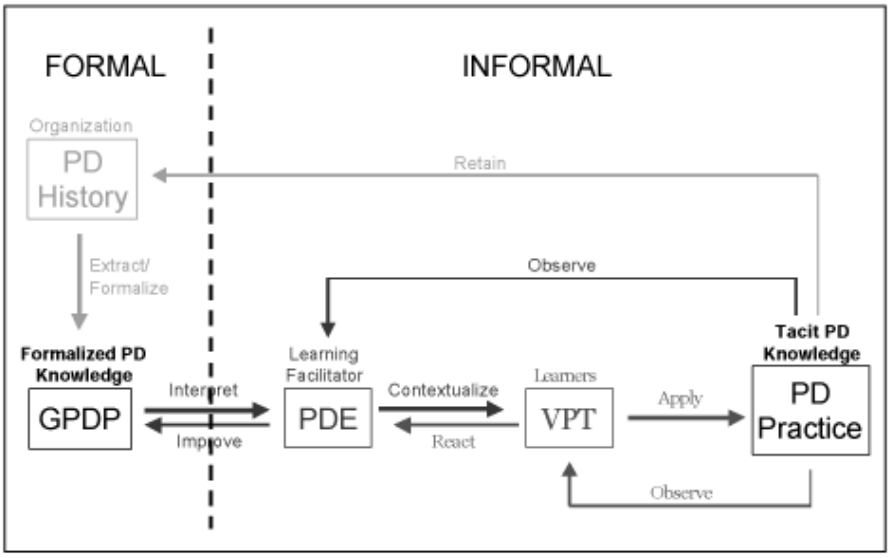

Fig. 3. A product development knowledge acquisition model based on the findings.

section, there are four conclusions that can be drawn from the findings of this study:

1. The formalized tasks and procedures embodied in a product development process need to be *interpreted* and *contextualized* for product development teams. Otherwise, what the process suggests does not appear tangible and valuable to teams, and runs the risk of being perceived as an overhead. What is of value to the teams is to contemplate the *intent* of the process—the rationale behind the suggested definitions and procedures. The intent of a product development process is not necessarily what can be formally captured and represented in flow charts, resource allocation tables, and task and deliverable definitions. On the contrary, it is mainly a *common* informal understanding of ways of doing the things that are necessary to develop a product, and relies heavily on the interactions of the involved parties.
2. Product development experts can be effective in accomplishing that contextualization by drawing on their own past as well as ongoing product development practices. In fact, it is critical that experts engage in—at least as an observer—the ongoing product development practices of the teams; the relevance of their interpretations increases when they are grounded in the situations they are interpreting for. Thus, for experts, an Observe-Interpret-Contextualize cycle forms the basic mechanism for facilitating the knowledge acquisition of teams.
3. However, when experts are deployed in order to facilitate the product development knowledge acquisition of the teams, two conditions arise as prerequisites to the effectiveness of the interaction:
   - No matter how much PD 'expertise' experts might have, it is difficult for them to be effective in facilitating the PD knowledge acquisition of teams without being and feeling welcome. If experts are not accepted at least as welcomed outsiders—if not as temporary members—to teams, biases teams might have toward what they are thought to represent is bound to influence how much they can learn from them.
   - The mechanisms experts utilize in facilitating the product development knowledge acquisition of teams must be *meaningful* for them. That entails the utilization of experts in situations where they are given the chance to interpret and contextualize the knowledge they are expected to convey to the teams. Utilizing experts as reference resources who respond to inquiries by merely 'relaying' information is not meaningful to them.
4. In such expert-team interactions, it is imperative that PD knowledge acquisition metrics are developed before product development processes and experts are deployed within the organization. Otherwise, it is very difficult to differentiate the improvements in product development practice due to expert facilitated knowledge acquisition from other factors such as the natural knowledge acquisition activity of teams and external conditions to the organization. The situation at Giant constituted an example where reliable metrics for assessing the effectiveness of the process and experts were not in place, and measuring their impact on product development practice proved to be problematic.

These findings indicate that product development knowledge cannot be embodied in a specific individual, a specific group of individuals, or a formal process. Those elements can only embody

aspects of product development knowledge. Interaction of those elements is what assigns meaning to the aspects of knowledge and allows for their synthesis. Therefore, it can be said that product development knowledge emerges out of the *combined interaction* of the involved people and resources.

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