Managing knowledge needs during new product lifecycle design on Quick-term Project Development QPD: *case study of 24 hours of innovation –ÉTS Montreal*

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Abstract. The research study analyzed the strategies used to managing knowledge during the definition of a new product, specifically, the conceptualization stage of preliminary product definition. This study analyzed knowledge needs and some performance conditions that R&D teams had to deal with within the context of QPD. The goal of this study was to understand the social and ICT factors that intervene during the process of product definition. A modified Benefit-Tools-Organization-Process-People (BTOPP) framework was used to describe the people, tools, processes and organization of R&D teams during the International Competition of "24 hours of innovation". Results show that teams require a wide range of ICTs and a flexible knowledge support system.

Keywords: new product definition, knowledge needs, BTOPP framework, knowledge management of product lifecycle, Quick-term Project Development.

1 INTRODUCTION

In new product development, there is an implicit distributed interaction among different actors, particularly when R&D teams envision new product functionalities or new product life-cylce. An R&D team has to forecast more than 5 to 6 years into the future lifecycle of a new product. They must also integrate new user's needs and technological changes. It is a genuine challenge for organizations to capitalize on these knowledge sources by trying to predict how the new product will perform in an unknown context. From the social perspective, the challenge consists in sharing knowledge and interconnecting people that are imagining these future conditions. The team's distribution of ideas and knowledge can be observed: we can observe knowledge sharing among R&D agents, a distribution of the subject matter knowledge implicated and also a distribution of personal interests in the new product development, all of which are in turn related to the interaction between the expectations of consumers, producers and distributors.

adfa, p. 1, 2011.

Table 1 shows the study conducted by Ulrich and Eppinger (2008) on the development of a new product which demonstrated that product complexity (number of pieces), organization team size (number of members in R&D implicated) and the time of development are all correlated. For a simple new product such as a screwdriver, at least three people are needed on the in-house team and three on the external R&D team (Ulrich & Eppinger, 2008). In a more complex product such as a Boeing 777, the internal design team is made up of 6,800 people and the external team and service suppliers consist of up to 10,000 people.

We can deduce that there also exists an interaction between different disciplinary knowledge fields with the result that contributions of each participant are interconnected to define the product lifecycle. The data also shows the role played by collaboration dynamics among the R&D staff and the main subjects for R&D, production and sales. The relationships between the size of design teams and variables such as product complexity - the number of pieces and the life cycle of a product - development time, sales lifetime, production investment and the sales price are also shown in Table 1.

Table 1 New Product resources comparison, by Ulrich and Eppinger (2008), p. 5

Product Development Needs	**Stanley Tools**	**Rollerblade**	**Hewlett-Packard**	**Volkswagen**	**Boeing**
	Jobmaster	In-Line	Deskjet	New Beetle	Boeing 777
	Screwdriver	**Skates**	**Printer**	**Automobile**	**Airplane**
Annual production volume (units/year)	100.000	100.000	4 millon	100.000	50
Sales lifetime	40 years	3 years	2 years	6 years	30 years
Sales price	$6	$200	$130	$20.000	$200 million
Number of unique parts (part numbers)	3 parts	35 parts	200 parts	10.000 parts	130.000 parts
Development time	1 years	2 years	1.5 years	3.5 years	4.5 years
Internal development team (peak size)	3 people	5 people	100 people	800 people	6.800 people
External development team (peak size)	3 people	10 people	75 people	800 people	10.000 people
Development cost	$150.000	$750.000	$50 million	$400 million	$3 billion
Production investment	$150.000	$1 million	$25 million	$500 million	$3 billion

ICT support needed for forecasting product lifecycle R&D or innovative teams

Despite the existence of an array of ICT services or knowledge toolboxes such as groupware options, extranet and intranet networks and databases that allow the knowledge exchange among R&D. The fact of adding communication tools did not alleviate the problem of effective exchange and communication in R&D teams. According with Gruber and Duxbury (2006) (cited by Dalkir, 2011), some possible causes are related to the difficulty of capturing knowledge that kind of forecasting knowledge, specially because the forecast information “is hard to find, there were different systems and no standards, the information was not where it should be, the tools were difficult to use and the database was difficult to access”(p. 234). It is not enough to have modeling tools to support knowledge sharing, because satisfactory team performance also depends on team dynamics: "training of knowledge retrieval, to define a knowledge strategy that would categorize in a standard way, to standardize the information technologies, and to create project web sites" (idem).

In the analysis of product lifecycle, we find approaches based in social demands as client requirements (Forgues, 2006), consumers participation (Helander & Jiao, 2002) or the product modelling with CAD technologies (Demoly, Monticolo, Eynard, Rivest, & Gomes, 2010; Quintana, Rivest, Pellerin, Venne, & Kheddouci, 2010). We observed that these approaches are complemented in a whole framework.

As the result of this reflection, we became interested in understanding and harnessing the complexity of managing knowledge needs of R&D teams: *What is the knowledge acquired by a team when forecasting new lifecycle process? What types of tools are needed create and share this knowledge?* We used the Benefits-Tools-Organization-Process-People (BTOPP) framework, proposed by Morton *(1975)* in *The Corporation of the 1990s*, and explained by Thorp (2012), to analyze the knowledge needs to define the product lifecycle as a whole system. BTOPP describes the benefits, the tools (information technologies), organization (structure and culture), people (skills and experience) and processes (management practices, procedures) (ibid, p. 72). Figure 1 shows an interpretation of BTOPP framework in defining the knowledge management system. The BTOPP framework was used to analyze the data collected in our case study/

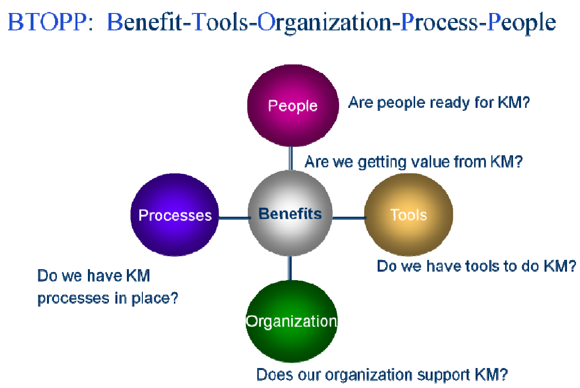


Fig. 1. BTOPP Framework of Scott-Morton adapted for knowledge management system by Dalkir, 2011

2 STUDY CASE DESCRIPTION

Our research team organized 24H, an international competition created by the École Supérieure des Technologies Industrielles Avancées (ESTIA) in France and sponsored by the École de Technologie Supérieure (ETS) in Montreal in partnership with 400 members of the Specialty Vehicles and Transportation Equipment Manufacturers' Association (AMETVS). The objective is to develop innovative solutions within the time frame of 24 consecutive hours. In the Fourth International competition, six universities participated, as shown in Table 2[1].

250 students, from a variety of design engineering disciplines and universities, were divided into 40 teams of 5 to 10 members. Each team could freely select one challenge[2]. to work on, given members' experience, knowledge and/or interests. They then had to come up with an innovative solution to their problem. This solution has to consider also all the product lifecycle process. The 24H teams developed complex interactions through the knowledge acquisition process used to solve problems as well as the knowledge that was shared to develop new products. Participants not only needed to interact with co-located team members, but also with remote organizational staff and industrial partners. In the early design stage, 24H teams searched for information in order to understand the context of the new product. This information delimited the design problem and defined the goal/task to draft the new product concept. Information was mainly through the Internet and distributed experts. They also made use of support tools. During the competition, the research teams completed an online questionnaire which captured biographical information and teamwork experience. Open-ended questions were sent every two hours asking which design process stage they were at, and what knowledge and tools they had needed and used. Participants then completed and submitted a final user satisfaction questionnaire at the end of the competition.

3 RESULTS

People: description of participants

Almost 250 students attended the competition and 142 agreed to participate in the research study. Each participant filled out the form every two hours only during periods in which they were working. On average, 50% completed and submitted the questionnaires. 57% were undergraduate students and 37% were Master's students. Approximately 73% said they frequently used from 1 to 5 groupware systems and 19% used more than 5 groupware systems. Most respondents were project development team members (69%) and 44% reported that had experience as a team leader. Students who had previously worked together tended to be on the same 24H team. 32% had not worked together for more than a year and only 19% responded that they had worked together for two years. 94% of participants reported that were comfortable working in teams. Table 2 shows how the teams were formed, including the number of members, the host university or institution and country of origin.

[1] For further information consult AMETVS´s website: http://www.transportail.com/en/nouvelles/nouvelle.asp?id=2230

[2] For more details, please see: Montreal version: http://etsinnovation.wordpress.com/2011/11/28/les-24-heures-de-linnovation-a-lets-les-gagnants-de-la-4e-edition-de-novembre-2011/

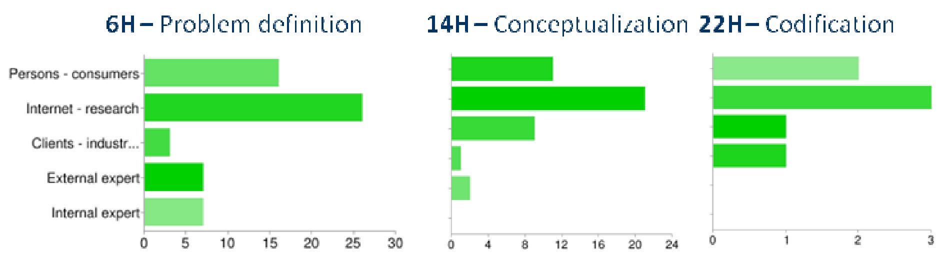
Table 2. Team composition by participants and school

Country	N.	Team	Participants	Institution	Domain
Belgium	T1	Les Zips	5	ESA - Saint Luc	Industrial Design, Mechanical Eng.
	T2	HEC-Ulg	6	HEC-Ulg	Bussiness
	T3	ICW	5	HEC-Ulg	
	T4	Limitless conception	7	HEC-Ulg	Economics, MBA
	T5	SAFEA's Troglodytes	8	HEC-Ulg	Economics, Bussiness Administration
	T6	La fourmilière	4	HEC-Ulg	Finance
	T7	ID-Brakers	5	HEC-Ulg	Economics
	T8	Groupe1	5	HEC-Ulg	Finance
Canada	T9	Les zombilistes	3	ETS	Industrial and Electrical Engineering
	T10	D-2913	6	ETS	Automatized Production Engineering
	T11	15HP	7	ETS	Informatics IT, Mechanical Engineering
	T12	INGénieuses	6	ETS,UTC TUBS	Mechanical Eng, Communications and Networks, Human Factors, Industrial Design, Aerospace
	T13	Innov'UTC	9	ETS, UTC	Automatized Production Engineering
	T14	Moonlight	3	ETS, UTC	Automatized Production Engineering
	T15	MidgETS	7	ETS, UTC	Logistics and Operation Engineering
France	T16	Kandasamy	3	UNIV-MLV	Mechanical Engineering
	T17	ESIPE -MLV	3	UNIV-MLV	Mechanical Engineering
	T18	ESIPE 1	3	UNIV-MLV	Mechanical Engineering
	T19	Purple	1	UNIV-MLV	Mechanical Engineering
	T20	ESTIA-Zip	3	ESTIA	Mechanical Engineering
	T21	Duck'y duck	2	UTBM	Design and mechanical Engineering
	T22	Les 6 fantastiques	6	UTBM	Design and mechanical Engineering
	T23	mécaZip	4	UTBM	Design and mechanical Engineering
	T24	Les tuques	3	UTBM	Design and mechanical Engineering
	T25	Les Woodchucks	6	UTBM	Design and mechanical Engineering
	T26	Innov in the soul	4	UTBM	Design and mechanical Engineering
	T27	The team of the time	5	UTBM	Design and mechanical Engineering
	T28	Duck'y duck	4	ISA	Agro-research
	T29	Duck'y deck	7	ISEN	High Technology and Innovation Design, Agro-research
	T30	Flo et les garcons	2	ISEN	High Technology and Innovation Design, Agro-research
	T31	Barnique-veritas	6	ISEN	High Technology and Innovation Design, Electonics and Informatics, R&D
	T32	Bazinga	4	ETS, Poly, UTBM	Design and mechanical Engineering
	T33	Seven-Team	4	ISEN	High Technology and Innovation Design, Electonics and Informatics
Reunion Island	T34	Team 1	5	Lycée Lislet Geoffroy	Electricotechnical
	T35	Team 2	5	Lycée Lislet Geoffroy	Electricotechnical
	T36	Team 3	5	Lycée Lislet Geoffroy	Electricotechnical
	T37	Team 4	5	Lycée Lislet Geoffroy	Electricotechnical
	T38	Team 5	5	Lycée Lislet Geoffroy	Electricotechnical
	T39	Choc	5	Lycée Lislet Geoffroy	Electricotechnical
Senegal	T40	Teamudz1	1	Université de Ziguinchor	Informatics
Total	**40 Team**		**187 Participants**		

ESTIA-École Supérieure des Technologies Industrielles Avancées
ETS- École de technologie supérieure,
ISA - École de l'agriculture, l'agroalimentaire, l'environnement et du paysage à Lille
ISEN- École d'ingénieur généraliste en haute technologie ingénieurs
Poly-École polytechnique Montreal
UNIV-MLV Université Paris-Est Marne-la-Vallée - Ecole d'ingénieurs par apprentissage des sciences et technologies
UTBM-Université de Technologie de Belfort-Montbéliard-
UTC-Université technologique du Compiègne

B. Process of knowledge acquisition

Managing the process of product definition must be considered as a “focus on end-to-end service delivery”(Jiménez-Narváez et al., 2012, p. 73). It is related with how “management practices and work procedures must be adjusted and changed to mesh with the major processes, such as product design and order processing" (idem). In this way, we identify a knowledge distribution in three axes constituted by three kinds of knowledge sources to achieve a new product development. First, we see the knowledge provided by the market and the valour chain: consumer expectations, distributors and sales information. Second, sharing knowledge provided by stakeholders and product designers, generally the information or briefing of a new product comes from sales, production and design departments. Third, knowledge about main technology or scientific knowledge involved in the new product conceptualization and the technological Watch results. R&D teams and partners have to integrate this variety of knowledge in a conceptual product definition. Figure 2 shows participants acquire knowledge to define a product from the Internet and search engines (45%) and from people or consumer information sources (27%). In the first stage of problem definition, 12% of the sources include external and internal experts and industrial constraints. The external expert also has a role at the end during the codification stage (14%). Industrial constraints are consulted 20% of the time during the conceptualization stage.



	6H - n	%	14H - n	%	22H - n	%
People - consumers	16	27,12	11	25,00	2	28,57
Internet - research	26	44,07	21	47,73	3	42,86
Clients - industrial constraints	3	5,08	9	20,45	1	14,29
External expert	7	11,86	1	2,27	1	14,29
Internal expert	7	11,86	2	4,55	0	0,00
Other	0	0	0	0	0	0

Fig. 2. Information sources for product definition in the early design stage

The open-ended questions identified the most important activities during the conceptualization stage, were: exchange of ideas about new technology development (including showing videos demonstrating existing technologies), brainstorming, discussions of different points of view on the prototype, use of different tools such as GoogleDocs so everyone could pool their ideas in one place, seeing commonalities, weighting ideas using criteria in order to identify the best idea and eventually achieving consensus on the unique solution. Participants used tools such as mind mapping, post-its or flip charts to define users' needs and conceptualize a solution using methodologies such as TRIZ[3] or C-K[4].

C. Organization

The structure of the organization is mainly related to teamwork dynamics and knowledge flow during the 24H session. At the beginning of event, as illustrated in Figure 3, Challenge Presentation (CP) stakeholders and Competition staff presented information using a PowerPoint presentation. This information was transmitted via a WebEx videoconference to participants in universities in France, Belgium and Senegal. Teams captured the knowledge needed to define a project using a knowledge toolbox that consisted of: search engines, patent database, and photos and videos (YouTube). The team also shared this information with some task and documents managers using Google groups, DropBox and email. Some participants used a LMS (Learning Management System) platform available to their universities. MS Project, MindManager, or Freemind were used to represent knowledge. This ICT richness decreased as the team defined the project more. Teams used paper-based tools in the second stage of Solution definition. Finally, ICT tools were only used for the Project Presentation (PP) stage, as shown in Figure 3. During this third stage, teams only used ICT technologies for a project outline, using standard design software and presentation tools (PowerPoint and MS MovieMaker).

D. Technology: use of ICT tools

As shown in Table 3, we assessed each team's ability to identify tasks and tools used for knowledge acquisition in three phases: "identification, conceptualization and codification" (Dalkir, 2012, p. 117). We assumed that task activity and project were strongly correlated with ICT technologies and also with knowledge sharing processes (Gottschalk, 2005; Rao, 2005b). Koulopoulos & Frappaolo (2000) affirm that ICT technologies are important vehicles for knowledge sharing because they mediate the interaction (groupware), contribute to knowledge externalization: sharing and retrieving documents, knowledge visualisation (portals); they contribute to knowledge internalization by providing training and resources to connect novices and experts (Learning Modeling Systems LMS), and finally, ICT technologies support workflows and decisions.

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[3] TRIZ, from acronyme russian ARIZ (Altgoritm Reshenia Izobretatelskih Zadach) is the Theory of Inventive Problems Solving proposed by Genrikh Altshuller in 1946. Altshuller studied more of 1000 patents to identified the algorithme ARIZ and 40 principles of contradiction used by inventors.(Kolb, 1984)

[4] C-K, Concepts and Knowledge, is a method of reasoning on design to define the limits between the concepts and the knowlege of a new product. Method developed by Hatchuel and collaborators.(Hatchuel & Weil, 2002)

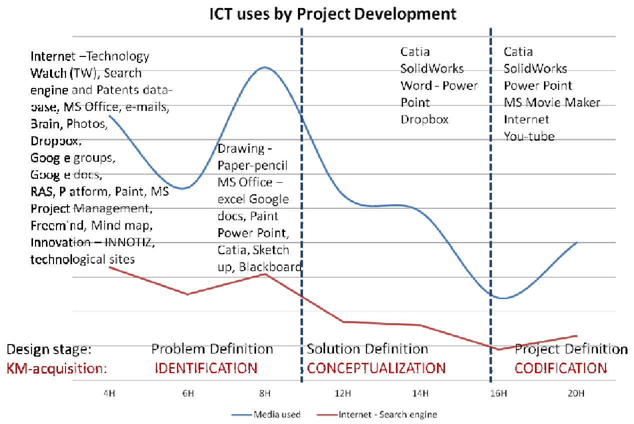

Fig. 3. ICT tools in knowledge acquisition during project development

R&D teams responded that they required tools tools "critical" to realize the project definition" (see Table 3). To assess these critical tools, we used the definition of "critical" need by Collins (2007), cited by Rao (2005a), who defines five levels of critical need "*critical*, *must have*, *important*, *nice to have* and *non-critical*" to sustain team performance.

Table 3. Critical tools to be used during a new product development

Project Stage	Activities	ICT –based Tool	Non ICT-based Tool
Problem definition	Inspiration Watch technology Art state	Internet Engine Patents Database Youtube	Simulations and body language
	Sharing links and files (Sharing content)	Google docs Google groups Dropbox	
	Brainstorming – collective idea production	Brain, Freemind	
	Discussion Communication tools	e-mail Skype (audioconferencing) Webex (videoconferencing)	Paper-Pencil Board – markets Post-it Verbal notations
Solution definition	Definition	Internet Engine Google docs MS-Word	Images Paper-Pencil Excel
	Idea definition	Catia, Rhinoceros MS-Power Point Blackboard	Drawings, plans, models
	Discussion Communication tools	e-mail Skype (audioconferencing) Webex (videoconferencing)	Paper-Pencil Board – markets Post-it Verbal notations
Project definition	Idea definition	Catia, Rhinoceros, Solidworks MS-Power Point MS Movie-maker	Drawings, plans, models
	Communication Tools	Dropbox Skype (audioconferencing) Webex (videoconferencing)	Co-presence or remote: verbal notations

E. Benefits

When R&D teams use KM practices, they profit from a "benefits flow"(Jiménez-Narváez et al., 2012). They improve their knowledge acquisition by consulting creative or innovative sites, particularly at beginning of problem definition. This activity consists of searching of images, photos and videos through Internet-search engines and innovation or technology websites. This allows teams to develop an effective strategy to envisage an innovative evaluation (e.g. through technology watch or functional analysis methods). Table 4 shows the Internet was used on average 25% to support this process. Contrary of the widespread belief on the importance of CAD software, R&D teams, at least at beginning of project definition, did not report extensive use of CAD until the conceptualization stage to define measures, establish volume/material or technical constraints. 15% used CAD for conceptualization and 17% used CAD for codification and presentation of the project. This demonstrates that R&D needs involve a wide range of ICT tools.

Table 4. Variation of use of ICT Tools during Project development

	Problem definition		Conceptualization		Codification	
Software Used	6H - n	**6H - %**	14H - n	**14H -%**	22H - n	**22H - %**
Skype - Webex - video conference	5	6%	4	6%	6	11%
Concept maps - mind mapping	5	6%	7	11%	2	4%
Drawing - Paint	14	17%	16	25%	7	13%
Internet - Search engine	25	31%	16	25%	13	25%
Photos, images or videos	16	20%	9	14%	9	17%
CAD	6	7%	10	15%	9	17%
Innovation sites - Methods	8	10%	2	3%	4	8%
Other	2	2%	1	2%	3	6%

4 CONCLUSION

Our goal was to model the process of knowledge acquisition and the use of KM tools for new product development and to describe the kind of knowledge management and resources (BTOPP framework) that can support the definition of a new product and its lifecycle so teams may be more effective in sharing ideas during a QPD project. We conclude that innovation tasks require knowledge acquisition tools that allow designers to easily manage information found on the Internet. R&D teams also need a flexible system of knowledge acquisition and sharing because the knowledge flow is variable and it depends on the design stage.

In this study, we demonstrated how the knowledge is distributed in different fields or disciplines. R&D teams work to compile the knowledge using a wide range of strategies and ICT-based tools. The BTOPP framework can be used to profile an integrated system of knowledge sharing between ICT-based tools and social dynamics.

In future research, we will focus on defining the causal relationships between the knowledge distribution, the use of Internet and the knowledge management system that could join together participants' knowledge production and sharing activities.

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