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Leveraging Web 2.0 in New Product Development: Lessons Learned from a Cross-company Study

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Abstract: The paper explores the application of Web 2.0 technologies to support product development efforts in a global, virtual and cross-functional setting. It analyses the dichotomy between the prevailing hierarchical structure of CAD/PLM/PDM systems and the principles of the Social Web under the light of the emerging product development trends. Further it introduces the concept of Engineering 2.0, intended as a more bottom up and lightweight knowledge sharing approach to support early stage design decisions within virtual and cross-functional product development teams. The lessons learned collected from a cross-company study highlight how to further developblogs, wikis, forums and tags for the benefit of new product development teams, highlighting opportunities, challenges and no-go areas.

Keywords: Engineering 2.0, Product Development, Web 2.0, Functional Product Development, Cross-functional teams
Categories: K.4.3, L.6.1, L.6.2, M.0, M.1, M.2, M.5, M.7

1 Introduction

Engineers are no longer solving the problems they used to solve. In the aerospace industry, for instance, the design of a new aircraft engine cannot merely be reduced to a pure technical activity, such as the calculation of stresses on the blades or on the intermediate case. Engineers are not longer dealing with "tame" problems only; rather have to pay increasingly attention to "wicked" problems [Rittel,73] as well, such as developing a "passenger-friendly" airplane [Boeing, 06].

The information and knowledge embodied into 3D product models and data structures, i.e. in CAD (Computer Aided Design), CAE (Computer Aided Engineering), PDM (Product Data Management), PLM (Product Lifecycle Management) and KBE (Knowledge Based engineering) applications, do not provide alone a good enough basis to support decision-making activities in this emerging context.

Whatever technical work is done it must necessarily be done in a social context – a context that encompasses the ordinary practical decision-making processes that individuals and teams go through, and the knowledge and skills they bring to bear on these processes. It has been observed that engineers and scientists very often turn to a person for information rather than to a database or a file cabinet, and people seem to

rely heavily on colleagues that they know and trust. Such informal, spontaneous and relatively unstructured interactions are therefore crucial to successful collaboration.

The increasing globalization, however,hasa negative influence on the knowledge sharing performances of development teams. Effective sharing is challenged by more distances than the geographical.Engineers are working together with more people than ever before, but often with very limited knowledge of whom they are actually working with, what their collaborators know, and to what extent they can be trusted. Differences include language, culture (both 'corporate' and 'local'), educational background, government regulations and time zones, thuslocal knowledge [Randall, 07] tends to stay local. Issues of how to build trust, rapport, and respect to bridge these differences are identified as crucial [Larsson, 2005].

To achieve effective global design teams, it is crucial to address and deal with such issues of "social disconnectedness". Social software represents a way to bridge this gap, offering the possibility to the engineers to create and maintain a rich network of connections with people with knowledge and experience in complementary domains. This is particularly interesting when it comes to product development activities, since that is a field where knowledge workers are explicitly interested in avoiding redundancy, and instead seek novelty and innovation rather than well-known knowledge.

2 Purpose and objectives

In this paper, the authors make the assertion that bottom-up, lightweight and Web 2.0 style technologies can have a serious potential when it comes to effectively share knowledge between actors partaking in product development in a global and virtual context. In spite of such an opportunity, companies find difficult to adopt and successfully exploit Web 2.0 methods and tools in the organization.

The purpose of this paper is to define and discuss the Engineering 2.0 [Larsson, 08] concept, highlighting the context it originates from and the way it may enhance collaboration across dislocated and cross-functional design teams. The paper spotlights the current initiatives aiming to introduce a more bottom-up knowledge sharing approach in the area of product development. Then, it collects application examples and lessons learned from a cross-company study, exemplifying how tools like e.g. blogs, wikis or forums can be applied in the everyday designers' work, and highlighting the major issues and the low-hanging fruits of Web 2.0 in product development.

A delimitation of this paper is its focus on "engineers", i.e. on the "engineering task" and on how Web 2.0 technologies can support globally dispersed engineering teams working in a business-to-business situation, where the available technology support for knowledge sharing still centres heavily on comparably "heavyweight" and top-down technologies like CAD, PDM, and PLM systems.

3 Methodology

The research has been conducted within a Swedish Excellence Centre for Functional Product Innovation, and has benefited from the participation to tworesearch projects in the European Commission's FP6 and FP7 programmes.

More specifically, a cross-company case study[Yin, 94] has been conducted within the Excellence Centre, in collaboration with an aircraft engine component and a machining tool manufacturer. Data have been gathered from 37 semi-structured interviews, two focus groups and several virtual meetings with people from the participating companies.

The companies were chosen as the main research context because of their rich experience with cross-functional global teams. The interview respondents belonged to different company functions (product development, customer support, marketing, production, IT service) and to different levels of the company hierarchy (process owners, project managers, company specialists, system users). The interviews have been made in six separate sessions at the company facilities between June 2008 and May 2010. The average duration of the interviews is about 40 minutes. Each interview was audio-recorded, transcribed, spell-checked and validated by the respondents. The excerpts presented in this paper have been taken from these recordings.

The interviews have been facilitated and moderated by the researchers to uncover topics that were not anticipated beforehand [Fontana, 1994] and to build on the findings from previous studies. An interview guide has served as a basis in the interviews, but, in line with semi-structured interviews, additional topics that came up in the discussion have also been followed up during these sessions.

The questions in the interview guide could best be described as open-ended questions, i.e. questions that allow the informant to formulate the answer from his or her point of view. One example of open-ended questions based on the topic "knowledge work" is: "Do you share your expertise within the organization? If so, how?".

Four virtual workshops with the company specialists have been arranged to validate the outcomes of the interviews and to further highlight priority areas of intervention.

The cross-company study has been complemented by 15 questionnaires forwarded to process owners and project managers belonging to major manufacturing firms mostly in Sweden, but also in Germany and Italy. The questionnaire included 13 multiple-choice questions, which aimed to gather data about the State-of-Practice of how cross-functional global teams collaborate, and 4 open-ended questions, to collect deeper information about the knowledge sharing barriers.

4 How Web 2.0 is spreading in product development: a review

Many organizations have started to investigate the use of Web 2.0 technologies in their working environment. MacAfee summarizes the rising company interest in the use of Web 2.0 tools for generating, sharing and refining knowledge in a global setting with the term Enterprise 2.0 [McAfee, 06]. Enterprise 2.0 is defined as "the

use of emergent social software platforms within companies, or between companies and their partners or customers". Shimazu [Shimazu,07] has further discussed the impact of Web 2.0 on knowledge management and its future orientation, introducing a knowledge management model in the context of the Web 2.0 age that can expand collective intelligence in a positive spiral by closely linking it to knowledge extraction from various communication tools and job systems. The Knowledge 2.0 [Levy,09] principles have been further explored from a generic company perspective by many authors, such as Scherp [Scherp,09], Sotirios [Sotirios,09] and Richards [Richards, 09].

For what concerns product development, the emerging interest towards bottom-up and lightweight applications has been highlighted by a recent McKinsey [Bughin, 09] survey, showing that more than 2/3 of 1700 companies interviewed worldwide have investigated or deployed Web 2.0 tools to support their product development activities.

Web 2.0 tools are not completely new in product development, although their use is limited to a comparably small part of the entire process, mainly with the intent of gathering ideas and feedback on the product from the customer base.

Crowdsourcing[Howe,06] represents the most intuitive way to leverage bottom-up tools for the benefit of product development. Crowdsourcing essentially means outsourcing a task to a large group of people or to a community (a crowd) through an open call. The basic principle is that online consumer communities greatly add value to new product development [Pitta,05], thus Web 2.0 can leverage the critical role that customers and the crowd play in the innovation process [Ribiere,09]. Crowdsourcing is hugely popular in the software development domain. Dell IdeaStorm [Di Gangi, 09] represents an example of how idea crowdsourcing may be exploited in an early design stage of new products. Several top companies, such as Microsoft, Apple or IBM, have made extensive use of social media to get feedback from the customer and to share ideas with lead users ahead of beta testing [Smith,09]. In manufacturing, Web 2.0 applications have been used to gather innovations for both products an services [Awazu, 2009] [Mamgai,09], sometime even by means of virtual prototypes online [Füller,06].

Web 2.0 tools have been also proposed to enable effective communication within dis-located teams, particularly to improve collaboration and shared understanding in the initial stages of a product development project [Walthall,09]. A lightweight knowledge sharing approach, based on a wiki-like annotation tool, to support distributed software development teams has been proposed by Maalej [Maalej,08]. The Microsoft Quest internal communications system [Patrick, 07] and the wiki-likeenvironment proposed by Ciavola et al. [Ciavola,09] represent other examples of bottom-up collaborative platforms. Social bookmarking applications, such as IBM Dogear [Miller,06], have also been developed to support learning, sharing and collaboration between researchers and professionals.

Similarly, Web 2.0 technologies have been proposed and implemented to support product development projects' documentation [Høimyr,07][Albers, 10]. Wiki-style collaboration tools can be used to create assessment reports [Hawryszkiewycz,07] or to address the problems associated with maintaining rule-based systems as they grow [Richards 2009]. Further, many companies have started to implement bottom-up application to harvestproduct and process ideas from their employees, distribute them

through the organization, have them evaluated by peers or formal review teams, and eventually to improve their offer and internal procedures [Awazu,09].

A more collaborative approach for knowledge retrieval has been also proposed by several authors, as a means to locate the right information just when needed. Context-based applications [Schillit,94] have been recently explored for the in-context delivering of relevant knowledge from previous design activities in order to improve future designs [Redon, 07]. The key element to successful reuse is to understand a designer's reuse intention, which is not merely expressed by few keywords in a query. Significant improvement can be obtaining by providing tools that allow users to express the applicability of a certain knowledge management to their context, and, therefore to use such information to further refine future searches and to provide more tailored knowledge to people with similar profiles [Redon, 2007].

Web 2.0 may alsodirectly enhance the traditional CAD/PDM/PLM tools through theintegration of social features. PTC, for instance, is exploring how to leverage social interaction and collaborative features, among global design teams, complementing CAD/PDM tools with Web 2.0 applications [Shoemaker, 09]. Vuuch (http://www.vuuch.com), a plug-in for Pro/ENGINEER or Dassault Systemes' SolidWork, initiates, monitors, and manages design discussions directly from the CAD environment to organize design discussions by associating them to the product Bill of Material (BOM).

5 Rethinking Web 2.0 to cope with the emerging product development trends

In a "traditional" product development situation, the product specifications are grown from high-level, pre-defined archetypes (e.g. a screwdriver, a car, a washing machine) and then refined in greater detail adding additional subsystem levels until the system is reduced to base elements in a hierarchical, top-down, flavour. The engineering work is typically co-located (i.e. the engineering team sits together in the same physical space) and well supported by domain-specific applications such as, to mention a few, CAD (Computer Aided Design), FEM (Finite Element Method), PDM (Product Data Management), PLM (Product Lifecycle Management), and KBE (Knowledge Based Engineering). These systems are proven to provide adequate support in managing structured product information and formal communication, such as project documents, design drawings, lessons learned, best practices records and others.

One of the industrial drivers that causes us to reconsider the knowledge sharing practices of product-developing organizations is the growing 'virtualization' of companies, making them increasingly loosely coupled – which has serious ramifications for the knowledge management practices and technologies that they choose.

Taking the aerospace industry as an example, very few companies have competences, knowledge and skills to cope with the development and supply of a complex product such an aircraft engine, composed by thousands of parts, with an expected lifecycle of 30-40 years.

A way to cope with such limitations is to establish a closer collaboration with a multitude of actors across the value chain, building strategic alliances with customers, suppliers, contractors, distributors, competitors and research centres [Isaksson, 09] and to be able to share knowledge in an open mode with them. Virtual Enterprise (VE) [Davidow, 92] are formed to access important information about, for instance, the role of consumers, retailers, customer support and maintenance [Isaksson, 09], which may allow to gain deeper insights into the basic reasoning that makes the customer link the use of a product or service to perceived added value.

To make an example, a jet engine manufacturer, such as Rolls-Royce, might develop engines to be used on both Airbus and Boeing aircraft, which are ordered by different airliners, which are partners in different airline alliances, etc. Further, the V2500 aero engine family is provided by International Aero Engines (IAE), a joint venture including Pratt & Whitney, Rolls Royce, MTU Aero Engines and the Japanese Aero Engines Corporation. Other examples of such virtual partnerships are both the CFM International, a joint venture between GE and Snecma aiming to develop the CFM56 aero engine product line, and the Engine Alliance (Engine Alliance)a joint venture between GE and Pratt & Whitney to develop the GP7200 engines powering the Airbus A380.

Traditionally, cross-enterprisepartnershipare led by a single Original Equipment Manufacturer (OEM), which can normally put its suppliers under contractual obligation to share data, information, and knowledge through one or several information systems of the OEM's choice [Browne, 99]. However, in the case of a Virtual Enterprise, the issue of what to share with others and how to share it is not as easily resolved, since a VE is essentially a network of independent companies, including suppliers, customers and even competitors, that are *"…linked by information technology to share skills, costs, and access to one another's markets. It has neither central office nor organization chart, no hierarchy, no vertical integration."* [Byrne, 93].

Defined in logical terms, not physical, the VE is based on the idea of organizations gaining access to more resources than they currently have available, without having to expand. Since VEsareessentially*"…networks of partners and suppliers that work together to reach common goals. In this environment there is no single partner that decides the infrastructure, tool set or processes to be used"* [McAfee, 06], there is the need to find tools that have a low overhead and are easily configured to be used by heterogeneous users. The prevailing hierarchical structure of the PDM/PLMsystems seems to contrast with the need to acquire knowledge and obtain feedbacks from a large network of independent and geographically dispersed peers. The development of an ad-hoc top-down collaboration platform is essentially too costly and time-consuming in this volatile context.

The authors have also observed a move towards extending traditional product-based offers to incorporate more intangible assets, i.e. software and services, taking on lifecycle responsibilities (in a nutshell, an evolution of the leasing/pooling model) to secure the aftermarket and to satisfy increasingly sophisticated customer needs.

In a Functional Products [Isaksson, 09] or Product Service Systems [Baines, 07] perspective the manufacturer maintains the ownership over the product and becomes responsible for the availability of the function through the entire life cycle, while requesting the customers to pay only for the provision of agreed results.

An illustration of the new "functional product" idea is apparent in the Total-Care Package [Shehab, 06] offered by Rolls-Royce plc. Rather than transferring the ownership of an engine to the airliners, the provider delivers "power-by-the-hour", requesting the customer to pay only for the use of the product (e.g. number of flight hours). In this way Rolls Royce can maintain direct access to the asset, enabling the monitoring of the product performances in use and growing experience on how the hardware is operated through the lifecycle. This information can be used later to improve maintenance schedules, engine efficiency, upgrade the hardware and, eventually, to increase the provision of lifecycle "value".However, "value" refers to different stakeholders and users, belonging to different organizations and groups, sitting in different locations, and who may have totally different perceptions on what "value" entails.

Intuitively, the knowledge base from which the product specifications are drawn has to be extended to know more about the ultimate customer needs, their value scale, and to tailor the hardware for a successful functional life. Engineers in an early design stage need to take crucial decisions regarding the structure of the functional offer and, consequently, they have to understand how a certain design alternative impacts on the stakeholders' value scale.

A jet engine could be kept in service even for several decades,thus knowledge from the 'later' phases (i.e. production, use, maintenance, recycling, etc.) now needs to be used as a knowledge foundation in the earliestdesign steps.A key challenge in such boundary-crossing product development work is that, for complex products like an aircraft engine, this value-related knowledge is dispersed across many different VE partners and customers (e.g. aircraft manufacturers, airlines, passengers, ground crew, airports, technical service) that use different technological systems to create, store and share it.

The knowledge contributors may have different roles, background, computer skills and may find cumbersome or even impossible to interact with domain-specific applications such as CAD, PDM or PLM, leading to a situation where the vast majority of people who might have knowledge about the emerging aspects of the product cannot contribute in populating the knowledge base.

Additionally, Bell [Bell, 06] argues from his study that 80% of the organizational knowledge is stored in people's heads, while only one fifth is formalized in Office documents e-mails, databases, XML data, etc. This informal knowledge exchange, which normally takes place by means of emails, phone conversations, face-to-face meetings or video-conferencing, is even more difficult in a VE context because the development team, as a whole, usually does not have a previous history of working together and there are fundamentally no 'shared assumptions' of how collaborative work may proceed. Additionally, there is an inevitable flux of team members over time in such projects, which makes even more difficult to share experiences, know-how and feedback.All these factors represent a great obstacle when engineers require authentic information, expert help, or when there is a need to search and retrieve quality information.

6 Engineering 2.0: a definition

Engineering 2.0 [Larsson, 08] is an approach that promotes the use of Web 2.0 style methods and tools to support informal knowledge sharing across functions and companies in a Virtual Enterprise setting (Figure 1).

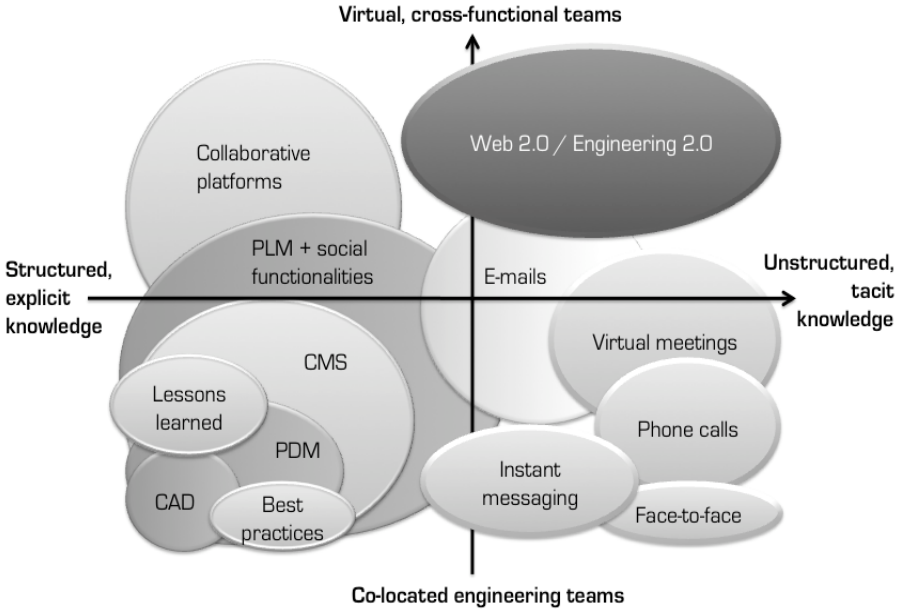

Figure 1: Engineering 2.0 mapped against current knowledge sharing approaches

The authors recognize that, to cope with upcoming product development trends, a more bottom-up and lightweight (compared with traditional CAD/PDM/PLM environments) approach for engineering knowledge management should be pursued. Lightweight because the purpose is to develop and implement solutions that require little time and effort to setup, use and maintain. Bottom-up because it does not impose a pre-defined structure, but rather lets structures evolve over time as an almost organic response to the activities, practices and interests of the knowledge workers that use these technologies as part of their everyday work.

The development and implementation of Web 2.0 style tools to support global, cross-functional collaboration has been extensively discussed with the companies involved in the cross-company study, which have pioneered the adoption of social tools within its product development department. The discussion has outlined areas where the benefit/risk ratio of Engineering 2.0 is particularly appealing for the company. The major benefits of are seen in the area of: new product opportunities identification, capabilities identification and design rationale management.

7 Identification of new product opportunities

When dealing with complex products and targeting lifecycle commitments, it is increasingly important to have a clear picture of a wide variety of customer needs and to identify opportunities to improve the current offer both from a product and service perspective.

The front line, the salesmen and technicians, may know a lot about the value of a solution for the customer. This knowledge is still mostly exchanged via customer visits reports or, informally, via face-to-face meetings, phone calls and spontaneous discussions, as outlined by one of our informants in the matching tool industry:

"Once, one of ourcustomerswas trying to optimize a blade machining processusing some of our toolsin his low-power machine. After a while, a technician visitedhis shop floor and noticed that he had been able to get significant process improvements by radically modifying the machining settings in a way we did not even expect in the beginning. He made a video, which was stored in a local database. However, it took several months before he could share what he saw with one of our product development engineers, and it happened by chance at the margins of a training event. The movie had been further analyzed and provided relevant knowledge for the next tools' development."

Web 2.0 tools could be usedto increase the product developers' awareness about what is "hot" at the customer today, facilitating the team in aggregating, filtering and validating the heterogeneous inputs from the front line. It is not merely a matter of forwarding the customer impressions to the engineers, rather to use the capabilities of the Web 2.0 tools to attach the right context to this information and to better trace how the needs originates and evolve.

The use of blogs and wikis to complement existing PDM/PLM solutions by leveraging conversations and putting them in a more global and shared context has been discussed with several company specialists:

"Blogs and wiki are powerful tools to pick up the coffee machine talks and to increase the network around a certain problem area... In the same way as engineers meet out in the corridor and discuss the matter, we can bring that discussion from the corridor into the wiki and nurture a more open dialogue."

Weblogs might be used as a platform for early feedback from external stakeholders and employees, allowing them to engage in discussions [Payne, 08] [Jim, 09] on product and service offers. They might provide a quick and lightweight way to codify the front line experience, letting other people with similar interest to rate, comment or ask for elucidations.New ideas and findings on innovation projects could be presented to a larger audience as an entry in the weblog, lowering the threshold for commenting and expressing opinions or document personal experiences.Wikis, similarly might also be used as a space to collaboratively grow ideas for future products and to define and refine best practices from the different lifecycle phases, facilitating idea and experience sharing among the stakeholders.

Alerts might be used to update the product developers about any changes in the global/local databases, while RSS feeds could allow design team members to

subscribe their choice of content resources to get regular updates in a standardized format, pushing relevant information to the users at the right time in the right place. Organizations might create RSS pages to accumulate all updates from various databases that are specifically customized for the employees' needs, and can help them getting an overview of the hot topics in the organizations.

Forums could allow engineers to raise critical issues with the other partners in the network, managing heavily moderated topical conversations over a prolonged period [Mayfield, 09]. They can be used to scale up internal conversations and to get feedback from experts in various domains and disciplines.

Tagging practices may facilitate the discovery of relevant knowledge outside the product development boundaries. The knowledge codified by the VE stakeholders may be put into different bins at a time (per customers, competitors, projects, product types, maintenance and service offerings) making easier for others to locate and fetch information tagged in the same way from different sources.

Microblogs might be used to spread innovative ideas, quotes, or links that may allow others to give real-time and focused feedback on technical or service matters. It might be possible to locate and follow experts in a VE setting, asking questions and getting answers, ultimately creating a learning experience and fostering professional connections.

The most evident benefits of Web 2.0 technologies relate to the possibility of reducing the time end effort to identify knowledge owners from the front line, to browse their inputs and to increase the awareness of the multi-functional issues regarding a given topic. Eventually the knowledge contributors may benefit from an increased awareness on people working in similar areas and, consequently, from the learning opportunity offered by their continuous feedbacks.

8 Locating the right capabilities in the organization

The study showed that social softwareplays a strong role in increasing the engineers' social ties, discovering people "who knows" and people "who may help" with a specific problem outside the usual network of connections. Design stakeholders who have similar knowledge, that share the same interests to solve complicated tasks or that possess complementary capabilities to cope with a given "wicked" problem, are difficult to locate in a global product development context, as outlined by one of our informants in the aircraft manufacturing industry:

"Our group comprises also a naval department. Once it developed an innovative and heavily press released engine model, which broke down at his first public ride. Then, at the annual corporate Christmas party, a group of naval engineers met experts from our aerospace division and started to discuss the accident. Plenty of issues not properly considered during design popped up. They went back to work, did the modifications, and it worked. I think we need these Christmas parties online. We have the right competences within our enterprise, but we are not good at finding them."

Social tools may support the discovery of people with the right expertise in the virtual organization, thus reducing the time needed to identify and allocate resources for a project.Moreover, they may help newcomers in exploiting the network of

connections that distinguishes more experienced engineers, finding people with the right expertise inside and outside the company, i.e. “knowing who knows” [Groth, 04], as clearly explained by one of the project managers interviewed:

“We have tested social software functionalities with some of our competence centres for internal questions. Instead of just talking to man next door, we can address someone who is faster and more acknowledgeable to answer them.”

Social bookmarking, as a method to store, organize and share bookmarks of web, may enable global engineering teams to search and find experts on specific topics, or people with similar interests in the projects, based on informal browsing of bookmark collections. Research engineers from various organizations can share their research with peers and allow others to rate and review to decide on usefulness of resources.

Nowadays it is quite common for companies to implement competence repositories, where to store information on the “knowledge owners” within the organization, such as the discipline they refer to or the project they have been working on. A major drawback is that such systems are increasingly difficult to populate and to keep up-to-date as time, as reported by one of our informants working in human resource management:

“We tried 4-5 times to create a competence database, (a formal template) where people were invited to describe their competences, the projects they have been working on, etc... They have been very hard to populate... People felt they were too structured, many fields didn't really matched... So we tried a new approach, letting people to freely describe and update their personal information themselves... What we see is that people are providing more information then before, and everything is very visible”

Moreover, such databases mainly collect information about people working within the reference organization, thus are useless when looking for people in the Virtual Enterprise, such as experts in other companies or in academia. Web 2.0 tools might be used to create cross-company “capability charts” to facilitate new design teams’ formation. People could be more easily searchable, their profiles would be more up-to-date, their network of connection would tell about their real interest and experience, and it would be possible to quickly get in touch with them and verify their availability in the beginning of a new project. The right match between people and projects will ultimately lead to better team chemistry, higher motivations and increased problem solving capabilities.

9 Capturing the design intent and its rationale

Web 2.0 toolsoffer the possibility to better capture the contextual information that traditional systems lack to record and communicate, like the reasons why a certain decision has been taken, by whom and under which conditions, and turning it into public for the benefits of the team.Design rationale management is another key area where the advantages of the lightweight and bottom-up paradigm are seen more clearly by the industrial partners:

"People may have very personal ideas on how an engine mount or a boss should be designed. Being able to formalize this unstructured information would mean that very early other people could say "this is good" or "this is completely wrong". We have a lot of views on how to do things, that means reinventing the wheel at every project… If we would be able to use social functionalities properly, the discussion could rise much earlier than it happens today and we could even keep track of the context in which information is generated."

The rationale for decisions taken in past projects is often lost or hidden in corporate databases that are not readily accessible by the design team once the project is closed. The arguments on which design decisions are based may become out-to-date, especially when the rationale comes from the later lifecycle stages and relates to the way the product is operated, serviced, maintained, dismissed or recycled.

To cope with the problem of keeping the design intent up-to-date, Web 2.0 technology can turn design rationale capture in a more bottom-up activity, involving a larger stakeholders' base in the codification of the argumentations for a certain design decision.Wikis may be used on the top of the existing project repositories to collect and give access to the underlying rationale regarding a solution even if the original documentation is secured. They also are seen as a good approach to cope with the lack of time for knowledge validation:

"There are many lessons learned documents in the company, but it stops at that point of being documented and nobody having time to review it. Wikis are one way to have design practices and lessons learned better validated."

Wikis, with their asynchronous, bottom-up and informal nature, may facilitate experience sharing among the stakeholders, building an informal memory for the Virtual Enterprise.

The use of Web 2.0 style tools to capture the design rationale has a deep impact on the decision-making activity for large, complex projects. In a stage-gate process [Cooper,08], tools such as wikis are seen as a promising approach to speed up decision making at the gate:

"A wiki system could support a more day-to-day process instead of waiting to a project gate before analyzing what information we have. A Wiki could help catching up all the potential lessons learned that support the gate passage and then co-ordinate the information more towards process improvement… Before a meeting, we could put in such a forum the most critical questions we want to discuss. If someone has the response before the meeting the discussion would rise even before the meeting starts."

Open authorship can leverage the way best practices or lessons learned are gathered from the different product life-cycle phases. Recommendations and context-based filtering may help to make a more efficient use of the design rationale maps, by supporting users in navigating their nodes and identifying the "golden nuggets" for a particular task. Tags may be used to cross-link map nodes in different domains and disciplines, while RSS feeds may aggregate and push real time updates to the engineers' desktop. Eventually, context-based filtering may be used to control the

access to the argumentation list, providing full access to a restricted group of people while excluding others

10 Discussion

The discussion with the industrial partners has outlined a number of issues from a methodological and technological perspective that need to be addressed before a wide adoption of Web 2.0 tools could be achieved. From a technological perspective, the availability of ad-hoc mash-ups coping with the specific engineers' tasks and interests is needed. On the methodological end, the availability of robust guidelines, especially concerning security and privacy issues, is seen as a major enabler for scaling-up the approach.

The active user participation is perceived as a major constraint. Incentive policies seem to be insufficient in a situation where engineers have to "do the job" and deliver within strict deadlines. Finding ways to further reduce the effort for knowledge formalization and exchange becomes an imperative, although it may not be enough in the long term. Even the lower threshold may be seen insurmountable if people cannot see the advantage of adopting the tools compared with traditional systems.

Mass participation in bottom-up initiatives can be obtained only by increasing the benefit/effort ratio of approach, both from the engineers' viewpoint as well as for all the other design stakeholders. This would mean: 1) providing customized knowledge at the right time, using other people's feedback to filter the query results on the basis of their applicability and pushing information to the end users; 2) supporting engineers in finding the unexpected, locating expertise and knowledge sources in the organization and facilitating the serendipitous discovery of "unknown unknowns" [Modica, 94]; 3) helping decision makers in recognizing relevant patterns, e.g. improving information visualization and aggregating inputs from many sources via ad-hoc mash-ups.

Knowledge validation is another critical aspect. Dealing with critical issues such as passenger security, it is more important to base decisions on verified knowledge rather then getting ideas, concepts and proposal from a wider base. Making the coffee room conversation public via blogs, forums etc. exposes to the risk of building a solution on knowledge that is not validated or tested, as outlined by one of our informants:

"If you write down a design practice, it is validated and approved. If you write something in a blog, it is not approved, but it is quite obvious that you cannot use it as it is. But the wiki… if somebody writes: "you should design a mount like this", someone else may decide to design it on the base of such information even if no one approves it. So, who is to blame? It is not a ranking system. Either you can design or you cannot."

As far as the solution is populated overtime, noise, spam and duplicated information increase as well, leading to a situation where the system is no longer lightweight, but cumbersome to navigate and poorly retrievable. Many of the respondents have expressed major concerns about the quality of the information shared in such a bottom-up fashion, since social applications tend to be dominated by

the loudest and most persistent voices, exposing engineers to the risk of developing critical solutions growing from personal opinions and interpretations rather than facts.

The leakage of proprietary knowledge is seen as a major threat while discussing Web 2.0 implementation in a cross-organizational setting. The possibility of letting the information flow in an open mode exposes the company to the risk of being drained of core know-how. Strict policies are advocated as the only means to regulate these flows, although it is not straightforward to understand how these could be established in practice. The lack of clear guidelines affects negatively users' participation too. Without clear indications of what could or could not be shared, users tend to "play safe" and rely only on the traditional CAD/PDM/PLM solutions.

11 Concluding remarks

The paper has explored the application of Web 2.0 technologies to support product development efforts in a global, virtual and cross-functional setting, analyzing the dichotomy between CAD/PLM/PDM systems and the Social Web under the light of the emerging product development trends.

The literature review as well as the cross-company studyhave outlined an increasing interest towards Web 2.0 style technologies in product development, together with a general lack of understanding on how they could be implemented to support everyday engineering work, i.e. "socializing with a purpose". The benefits of using social media to cope with the engineering tasks are not evident to most of the potential users. Today's perception of the usefulness of mash-ups combining, for instance, blogs, tags and RSS feeds, is particularly low, even in Virtual Enterprise situations where the need for social functionalities might appear more evident at a first look. Moreover, Engineering 2.0 can have negative consequences on the preservation of company's proprietary knowledge, e.g. pushing confidential information to unknown subscribers. Strict policies concerning dissemination of sensitive material are advocated as the only possible solution, although the risk of spoiling the approach of its innovative potential becomes higher. Many concerns about the quality and maturity of the information exchanged have also been raised. One of the major risk is to develop a knowledge sharing solution dominated by personal opinions and interpretations rather than verified facts.

In spite of all these potential drawbacks, the opportunity of leveraging a more bottom-up and lightweight approach for knowledge sharing in the area of opportunities identification, cross-functional teams composition and design rationale capturing is widely seen. From a methodological perspective, it will be crucial in the future to investigate how the lightweight approach may increase design teams capabilities to prevent mistakes in design rather than correcting them. Engineering 2.0 should not merely support the design team in the classical "recognizing symptoms - implementing corrective actions" working mode, rather it should support designers in preventing mistakes, helping engineers in performing more effective root-cause analysis. At this purpose, an Engineering 2.0 demonstrator is under development to collect feedbacks on the use of lightweight and bottom-up techniques in a cross-functional and cross-company design situation.

The field study has also highlighted that the benefits associated to a more bottom-up and lightweight knowledge sharing approach are difficult to communicate in a

product development context, mainly because methods and techniques cannot easily be related to dimensions relevant for the engineering teams. Currently under development is a categorization framework [Bertoni, 10] to benchmark Web 2.0 applications, underlining similarities and differences in a meaningful way for engineers, and to qualitatively evaluate how technology mash-ups could support the knowledge sharing activity in a cross-functional context.

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