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The Rise of Social Product Development

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Abstract: The aim of the paper is to discuss the rising potential of social software to increase the knowledge management capabilities of virtual product development teams. It presents six fundamental transitions, elaborated from the empirical findings, which justify the rise of a more bottom-up, social creation and sharing of engineering knowledge in the virtual organization. The study suggests that traditional engineering knowledge management approaches alone are not sufficient to support development activities in the virtual organisation, and that such teams display an increasing demand for social, comparatively lightweight and remixable platforms for bottom-up, social creation and sharing of knowledge.

Introduction

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 knowledges and skills they bring to bear on these processes. It can be argued that design work simply cannot take place without this social enactment. To put it another way, design work is always and inevitably a socio-technical business, intertwined in the: "…meetings that produce the specifications; the discussions around rough calculations and sketches that create understandings among the participants; the arguments about interpreting test results and prototype qualities that contribute to 'feel' and 'intuition' about aspects of the design; and the debates about whether the design is 'done', if the specifications have been 'met' and if the result is 'good." (Minneman, 1991, p.63)

The balance between the social and the technical (Bucciarelli, 1984, p.187; Bucciarelli, 1994) in engineering practice is visible, for instance, in the informal and opportunistic ways in which people exchange information, advice and experiences with each other throughout the course of their work. It is crucial to understand that such relatively casual interaction is not additional to the technical work that engineers perform, but is constitutive of the design process.

In engineering, social capital (Putnam, 2000; Cohen and Prusak, 2001) is of particular importance since engineers fundamentally deal with ambiguous requirements and problems, which means that trust in people and their expertise is essential to successful decision-making (Larsson, 2005). Engineers in the automotive industry, for instance, rely on social relationships to carry out their work; to find out 'who knows', to figure out 'who to trust', to negotiate shared understandings, and to bridge gaps between different domains of expertise (Larsson, 2005).

However, engineering designers and other actors in the domain of product development, are continuously expanding the number of teams and projects they are participating in, and they are working in a global context to a far larger extent than before. Such increased virtualisation challenges the development of social capital and trust among the teams (Striukova and Rayna, 2008). Thus, individuals in product development are facing a situation where they are working together with more people than ever before, but often with a very limited degree of know-who: the interpersonal relationships that enable people to ‘know who knows’, to ‘know who to ask’ and to ‘know who to trust’ (Larsson, 2005).

A major problem is that local knowledge (Randall, Harper and Rouncefield, 2007, p.240) tends to stay local. Multinational Enterprises (MNEs), for instance, face major impediments due to their relatively low capacity of absorbing knowledge from internationally dispersed units (Araujo, 2009). In the domain of engineering and product development this is not only a problem related to individuals and teams being geographically dislocated. It is also related to companies putting a strong emphasis on knowledge management technologies that deal mainly with formal, structured data and information (e.g. Computer Aided Design, Product Data Management, Product Lifecycle Management, etc.), thus often neglecting the informal, relatively unstructured interactions that may be so crucial to successful collaboration.

Capturing, sharing and reusing decision rationale throughout the product development process is becoming increasingly difficult with an escalating social, geographical and temporal distribution of knowledge (Randall et al, 1996). For instance, the information contained in the abovementioned knowledge management systems is primarily targeted to other engineers, thereby missing the opportunity for the organisation to transcend corporate and disciplinary boundaries in its knowledge management practices.

This paper argues that a radically changing industrial context, merged with the perceived potential of social software, has brought us into the dawning age of social product development, where social software can help engineers and others working in product development to more effortlessly and effectively develop the ‘know what’ (Ryle, 1984), ‘know-how’ (Ryle, 1984) and ‘know-who’ (Larsson, 2005) needed to achieve their objectives. The paper seeks to:

- present the recent trends that justify the need of developing and implementing social technologies in the context of product and service development;
- clarify the key characteristics of the concepts Web 2.0 and Enterprise 2.0, and elaborate on their meaning from the perspective of engineering teams in the virtual organisation;
- present six fundamental transitions that justify the rise of a more bottom-up, social creation and sharing of engineering knowledge in the virtual organization.

Methodology

The study has been performed within the frameworks of two research projects in the European Commission’s FP6 and FP7 programmes, and builds on data from three different companies in the aerospace industry. Our participation in the research programmes gave some implications, which delimited the choice of research approach.

Action research is an approach that is commonly described as iterative activities performed by practitioners and researchers jointly (Avison et al., 1999; Stringer, 1999), which is thus in alignment with how we could perform our research in these projects.

On an overarching level, action research follows a particular cycle of activities, namely problem diagnosis, invention and reflective learning (Avison et al, 1999). The challenges related to engineering presented in this paper have their origins in the problem diagnosis phase. Empirical qualitative data have been generated by the authors’ active participation in the organised work-meetings and further analysed in debriefing activities. Data have also been generated in 17 semi-structured interviews with 14 persons from one of the participating companies, belonging to different functions (product development, customer support, marketing, production, IT service) and at different levels of the company hierarchy (process owners, project managers, company specialists, system users). The interviews were made in two separate sessions at the company facilities between June 2008 and February 2010. Each interview was audio recorded, transcribed, spell-checked and validated by the respondents. Excerpts presented in this paper have been taken from these recordings. 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 interviews have also been followed up during these sessions. Two virtual workshops with the company specialists were also arranged after each session with the purpose of discussing and validating the outcomes of the interviews and to further highlight priority areas of intervention.

Typically, for action research activities and for the generation of qualitative data it is hard to separate the analysis parts from the data generation parts since these are intertwined activities. However, an effort has been made to emphasise the practice and the informants' point of view. It should be noted that the 'social' factors that this research explores are not readily available without some observation of informal processes and that even interviews have to be drawn on the background knowledge that the researchers have acquired.

An Industry in Transformation

From Tame to Wicked problems

One of the major reasons to why product developing organisations need to care more about the social creation and distribution of knowledge is that their engineers are attempting to solve problems of a different order to those of the past. Rittel and Webber's (1973) notion of 'wicked problems' is more relevant than ever, as it points to a paradoxical situation where you cannot clearly define the problem until you have solved it. The problems that engineers now are posed with are increasingly problems for which all the necessary information will never be available to them and where requisite information and knowledge may be held in a number of different locations and in any number of formats (Cross, 1982, p.224). These problems are often poorly posed, lack a readily identifiable closure, and require the integration of knowledge from several subject areas, held in differently structured repositories, possibly with different terms (Hyman, 1998, p.3). Ackoff (1999) recognises that many problems are not individual or isolated, and that they are rather a 'system of problems' – what he calls a 'mess'. A solution to such messes cannot be obtained by solving each of the problems separately, the system must be considered as a whole, and cannot be divided into independent parts without losing its essential properties. Consequently, Ackoff argues, the performance of the whole system is not automatically improved when individual parts of the system are improved. Similarly, Checkland (1981) argues that while 'hard' systems thinking is effective when applied to well-defined (e.g. entirely technical) problems, it is not suitable for 'soft' problems involving human or social components. If such writers are correct, there is a need for a radically new perspective on what the 'engineering problem' looks like and what potential solutions might be available. Both identifying the problems and finding the solutions will necessitate, we argue, close attention to the socio-technical.

From Product to Function

Product-oriented organisations are increasingly shifting their scope from selling ‘hardware’ to providing ‘functions’ (Ericson and Larsson, 2005) with the purpose of delivering added value to customers (Lindahl et al., 2006; Baines et al., 2007).

In this new scenario, the manufacturers maintain the ownership of the product and expect the customer to pay only for the provision of agreed results. TotalCare® offerings (Harrison, 2006) by the aircraft engine manufacturer Rolls-Royce, for instance, aims to provide “power-by-the-hour” as a means to: “…improve product availability and reduce the cost of ownership by tying a supplier’s compensation to the output value of the product generated by the customer (buyer)” (Kim, Cohen and Netessine, 2007). Power-by-the-hour agreements imply that there is no effective transferring of engine ownership to the airline, but rather the engine provider requests the customer to pay a fee proportional to the number of hours the engine has been used (Harrison, 2006).

When developing such offers, providers have to consider a wide range of development and use scenarios as early as possible in the development process. Providing a function means that the provider becomes directly involved in the cost of operation (Boart, 2005), and that maintenance, repair and overhaul becomes a cost instead of a profit. A jet engine could be kept in service for as much as 30-40 years, therefore knowledge from the ‘later’ phases of the product lifecycle (i.e. production, use, maintenance, recycling, etc.) now needs to be used as a knowledge foundation in the earlier phases of the product development process.

It is highly important, therefore, to investigate how such different knowledge could be made available to a wide range of actors, to improve early-stage decision making. To what extent should services be ‘designed-in’ or ‘added on’? What competences and knowledge are needed for the development and the provision of use of performance?

As the scope of early product development activities rapidly changes, organisations need to share and utilise a wider array of data, information and knowledge that has previously not been readily available in a traditional product development context.

From Extended to Virtual Enterprise

The growing ‘virtualisation’ of companies and the continuous and capricious change of value networks (Oksanen, Hallikas and Sissonen, 2010) are among the major industrial drivers that cause the authors to investigate social technologies for product and service development. Extended Enterprises (EE) (Browne and Zhang, 1999) and Virtual Enterprises (VE) (Davidow and Malone, 1993) are two examples of partnerships that are common in aerospace. EE are often 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.

VE is essentially a network of independent companies, including suppliers, customers and even competitors, that “… is linked by information technology to share skills, costs, and access to one another’s markets. It will have neither central office nor organisation chart. It will have no hierarchy, no vertical integration.” (Byrne, Brandt, and Port, 1993, p.98). For example, 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.

Here the issue of what to share with others and how to share it is not as easily resolved, because “…In this environment there is no single partner that decides the infrastructure, tool set or processes to be used“ (McAfee, 2007). This raises the questions of how to find tools that have a low overhead and are easily configured for use by heterogeneous users. In this article, we argue that social software offers exactly this functionality.

Social Software

Web 2.0

Grossman and McCarthy (2007) note that a compelling aspect of Web 2.0 is that it creates an 'architecture of participation', allowing the average user to play an active role in creating content. Similarly, O'Reilly (2005) writes that one of the key lessons of the Web 2.0 era is that users add value, further noting that "…only a small percentage of users will go to the trouble of adding value to your application via explicit means. Therefore, Web 2.0 companies set inclusive defaults for aggregating user data and building value as a side effect of ordinary use of the application. As noted above, they build systems that get better the more people use them." The simplicity of Web 2.0 technologies offers a few key characteristics that have particular relevance for the highly distributed, highly cross-functional Virtual Enterprise. To reap the benefits of Web 2.0, companies need to:

- Support lightweight programming models that allow for loosely coupled systems (i.e. in line with the loosely coupled VE network)
- Support syndication rather than coordination of data (i.e. content will flow from the bottom-up rather than from the top-down)
- Support re-use and remixability in an open-source model (i.e. content can be used for other purposes than for which it was originally intended)

Enterprise 2.0

McAfee's (2006) concept of 'Enterprise 2.0' includes new digital platforms for generating, sharing and refining information, focused not on capturing knowledge itself, but rather on the practices and output of knowledge workers. (McAfee, 2006, p.23) Thus, it can be seen as a specific application of Web 2.0 tools for the purpose of doing business more effectively. McAfee argues that while knowledge workers use channels (e.g. e-mail, instant messaging) and platforms (e.g. intranets, information portals) all the time, the problem is that the channels they use cannot be accessed or searched by anyone else, and their visits to platforms leave no traces. "Thus, the channels and platforms in use aren't much good at providing answers to such questions as: What's the right way to approach this analysis? Does a template exist for it? Who's working on a similar problem right now? When our Brazilian operation reorganised last year, who were the key people? What are the hot topics in our R&D department these days?" (McAfee, 2006, p.23)

Social Product Development: Engineering 2.0

Based on the authors' empirical work, it is possible to highlight a number of unique features that stress the importance of leveraging the "networking effect" of knowledge sharing technologies and practices in a virtual organisational context:

1. Virtual Enterprises are 'loosely' coupled networks of independent partners, established on a project-by-project basis.
    a. Knowledge workers in enterprise-wide teams do not normally have a shared history of working together.

   b. Knowledge workers in enterprise-wide teams do not normally have a shared knowledge base with lessons learned, best practices, etc.
   c. Knowledge workers move in and out of enterprise-wide teams as different competencies and capabilities are needed.
   d. Knowledge workers in enterprise-wide teams do not normally have a shared set of technological systems to create, store and share knowledge.

2. Development of ‘functions’, rather than ‘hardware’, as part of total life-cycle commitments radically changes the scope and objectives of engineering activities.
   a. Knowledge workers will need to increasingly work in highly cross-functional, cross-disciplinary, enterprise-wide teams.
   b. Knowledge workers will need to develop closer relationships with customers and suppliers, to better understand the desired ‘function’ to be developed.
   c. Knowledge workers will need to improve their understanding of their contribution to the overall development and product life-cycles.
   d. Knowledge workers will need to make their knowledge available to a much larger audience than before, and will also need to use knowledge from many more sources than before.

In such a perspective, Engineering 2.0 is an approach that emerges from the concepts of Web 2.0 and Enterprise 2.0 and that promotes the use of bottom-up mechanisms to support informal knowledge sharing across functions and companies for the benefit of engineering work. Engineering 2.0 follows a Knowledge 2.0 (Levy, 2009) trend aiming at complementing “traditional” top-down knowledge sharing approaches with simpler and more flexible (Avram, 2006) tools, as a way to remove knowledge acquisition bottlenecks in organisations by providing necessary support for conversations and collaboration in emergent ways (Wagner, 2006). The Windchill ProductPoint platform (http://www.ptc.com), Dogear social bookmarking (www.ibm.com) and SolidWorks Tagger (www.solidworks.com) are some of the most notable examples of this trend in the engineering domain.
Engineering 2.0 is, by definition, “lightweight” compared with the existing systems. The term ‘lightweight’ principally means that the technologies:

- require little time and effort to set up, use and maintain (i.e. lowering the threshold for adopting the technologies);
- do not impose a pre-defined structure (i.e. letting 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;
- support informal communication also in absence of physical proximity (i.e. by capturing also the subtle, spontaneous, and multidimensional messages that characterise personal interaction).

One of the main misconceptions of engineering is that all the relevant product data, properties, information and knowledge has already been captured, and is easily accessible from Computer Aided Design (CAD), Product Data Management (PDM), or Product Lifecycle Management (PLM) systems. Engineering 2.0 aims to complement the available technology support for knowledge sharing, which still mainly centres on these systems, and on other collaborative workspaces. However, Engineering 2.0 is not intended to replace CAD/PDM/PLM platforms, rather the aim is to support engineers in finding new ways to deal with problems related to the development of 'functions' in a virtual context, and that are not adequately addressed by 'heavyweight' systems alone.

Six Transitions for Knowledge Management in Engineering

Based on the empirical work carried out in the aerospace industry, this section will be used to highlight six fundamental transitions (see Table 1) that companies need help dealing with as they switch focus from product to function, and thus are partnering with other companies in Virtual Enterprise constellations to take on total life-cycle commitments. Fieldwork examples will be used to initiate a discussion of how particular 'social' capabilities of software could be used to purposefully address some of the most demanding Virtual Enterprise challenges.

Table 1: Six transitions for Knowledge Management in engineering

#	Transitions
1	**From Weak to Potential Ties** Transcending local relationship boundaries in the search for novelty and innovation.
2	**From Personal to Public Benefit** Deriving public benefits from personal actions, without imposing additional work on knowledge workers.
3	**From Predefined to Emergent Structures** Avoiding imposing high-threshold control structures that control user behaviour.
4	**From Lookup to Exploration** Assisting knowledge workers in moving beyond known item searches, fact retrieval and question answering.
5	**From Directional to Intersectional Innovation** Entering into the intersection of fields, disciplines and cultures to create extraordinary new ideas.
6	**From Teams to Crowds** Keeping social ties loose to expose knowledge workers to as many diverse sources as possible, across hierarchies.

Transition 1: From Weak to Potential Ties

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. Our research indicates that 'knowing who knows' (Larsson, 2005) is crucial in global engineering design teams and while that seems to be a commonly accepted feature of collaborative work, it also poses a severe threat to virtual organisations, where this kind of 'engineering know-who' (Larsson, 2005) is not as easily developed as in more traditional enterprise settings. Unlike traditional workplaces, the nature of virtual teams is such that working relationships are typically short and often there is no actual personal contact (Young, 2008). To achieve effective global design teams, it is crucial to address and deal with such issues of 'social disconnectedness'.

The concept of 'weak ties' (Granovetter, 1973) points to the value of establishing personal relationships that transcend local relationship boundaries both socially and geographically. For example, Granovetter's research on weak ties has indicated that a person looking for a job is, for certain professions, more likely to find a new job through an acquaintance rather than through a close friend, much because the acquaintance is more likely to move in other social circles, and is also more likely to possess other information than what you already have. Social networking software, such as LinkedIn or Facebook, and blogs and wikis are some of the ways in which engineers can both increase the density of their weak ties, and get connected to people with knowledge and experience that is new and possibly complementary rather than well-known and possibly redundant. 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 seeking novelty and innovation.

However, what would be the output if VE:s could also better harness the power of 'potential ties'? (McAfee, 2008) This notion includes "…a still-larger set of fellow employees who could be valuable to our prototypical knowledge worker if only she knew about them. These are people who could keep her from re-inventing the wheel, answer one of her pressing questions, point her to exactly the right resource, tell her about a really good vendor, consultant, or other external partner, let her know that they were working on a similar problem and had made some encouraging progress, or do any of the other scores of good things that come from a well-functioning tie." (McAfee, 2007).

The power of weak ties was exemplified by one of our informants in the aerospace industry: "We belong to a big manufacturing group including also a naval department. Once the naval guys developed an innovative engine model, which was heavily press released but that failed to work when they made a first public ride with it. Then, at the annual corporate Christmas party, they met some of the guys from our aerospace sector and started to discuss the accident. During the discussion our guys pointed to plenty of issues that had not been properly considered during design, so the naval guys went back to work and did the modification, and it worked. I think that's a great story, because we have the right competences within our enterprise, but we are not that good at using them. I think we need these Christmas parties online, where you can easily send out the questions, and the community may give you a feedback."

To really harness the knowledge that is dispersed across the VE, we need to recognise that the foremost experts on your products might not be on your payroll, and that there might be 'hidden experts' around the enterprise, who are willing to volunteer outside of their official job description (Mayfield, 2007). Also, of course, these potential ties could be 'lead-users' (von Hippel, 1986), in any part of the customer network, offering their advise and experience, whether you asked for it or not.

Transition II: From Personal to Public Benefit

This article discusses lightweight technologies for knowledge sharing, and if a technology is perceived as 'lightweight' or not naturally depends on the benefits derived from using such technologies. If the personal benefits are large, i.e. if the return on investment is high enough, users might even tolerate a slow and tedious system because the results are considered worth the extra effort. Similarly, even the lowest threshold could be considered too large if the results are not benefiting the user. One could argue that one of the reasons why many projects are poorly documented is that project participants have difficulties seeing the benefits of making this extra effort to capture rationale, experiences, lessons learned, etc. The people who have to do the extra work are normally not the people who will reap the benefits.

Tang et al. (2007) performed a study on how knowledge workers in a workplace environment store and manage files on their workplace computers, to see if any social patterns could be identified for the benefit of the company. The interesting thing here, from a social product development perspective, is that identifying these collaboration patterns did not require any additional work by the user. These patterns fell out of the work users are already doing in managing and storing files concerning information that they care about.

When attempting to lower the threshold for knowledge sharing, this is a highly appealing concept. If what people are doing as part of their everyday work produces traces and patterns of how they create, use and share knowledge, why not use these traces and patterns to achieve public benefits across the VE? The social effects of using social software are sometimes unintended – which is something of a paradox. Knowledge workers do not have to put extra effort into sharing knowledge across social networks, but other people in the enterprise can still make sense and use of the traces they produce. In a VE context, where the social ties between knowledge workers are relatively few and weak, or even non-existent, to start with, the ability to derive public benefits from personal actions is very interesting.

One of our informants at an aircraft engine components manufacturer noted the possibility to better capture the informal communication and unstructured information and to turn it into public benefit for the team: "People may have very personal ideas on how an engine mount or a boss should be designed. Being able to formalise 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 these social functionalities properly, the discussion could rise much earlier than it happens today."

From a company perspective, this transition is partly driven by the need of reducing risk in the new technology innovation programs: "…We need to collaborate even earlier with the aircraft OEMs, engine OEMs and systems OEMs to be better prepared from a technology perspective time-wise… Developing a new engine technology may require 10 years. The only way we can reason 10 years ahead is to capture the unstructured information, i.e. the coffee room conversations… We need to bring these discussions into a more open and shared space, where other people can address relevant questions, give comments, and have open dialogues, so we can increase the network around certain area/issues."

Here, the concept of a 'folksonomy' (Vander Wal, 2007) makes sense, much because, as opposed to a taxonomy, people "…are not so much categorising, as providing a means to connect items (placing hooks) to provide their meaning in their own understanding." (Vander Wal, 2007) This provides opportunities to find emergent vocabularies and trends, and since information tagged for personal use can benefit other users (Golder and Huberman, 2005) across the enterprise, this could allow knowledge workers to find people across the disciplinary, departmental and organisational boundaries of the VE. Rather than relying entirely on up-front decisions about where in the enterprise to look for relevant knowledge and persons, finding people who tag items the same way they do, will allow knowledge workers to find social groups based on similar interests and ways of speaking and acting, rather than based on where they are placed in the organisational chart. Braun, Kunzmann and Schmidt (2010) highlight that competency profiles are often incomplete and out-dated, partly due to lack of participation of employees. Thus, they propose a collaborative approach based on Web 2.0-style people tagging, complemented with community-driven ontology engineering methods.

Apart from the benefits related to uncovering knowledge that you could not normally access through conventional interviews or observations, McAfee (2007) points to some interesting networking effects. As more people author, link, search and tag information, the emergent structure becomes increasingly fine-grained: "They can make large organisations in some ways more searchable, analysable and navigable than smaller ones, and make it easier for people to find precisely what they're looking for." (McAfee, 2008).

Lightweight technologies can also provide public benefits by increasing the common understanding of data and information stored inside and outside the organisation. For instance, a document repository that contains most or all of the structured content produced by project members is typically undecipherable to people outside the project, to people who join the project after it is underway, and even to the original project members after time has passed (Grudin, 2006). Since knowledge assets need to be maintained over time, it becomes increasingly important to record the contextual dimensions related to such content, since people may leave the organisation, new partners may join the project, or new needs and requirements may emerge along the way. Lightweight technologies for knowledge sharing can support engineers in providing a context to the documentation stored in company databases. Blogs, for example, may be used to provide easily-skimmed chronologically-ordered records of the important events of a project (i.e. status changes, etc.) that may give knowledge workers a deeper understanding of how the work is being performed in the project and why it is being done in a certain way.

Transition III: From Predefined to Emergent Structures

One of the defining features of lightweight technologies is that they do not impose a predefined structure to how these systems 'should' be used. The intelligence of such systems is, instead, provided by users in low threshold ways, where control is shared with users to create value (Mayfield, 2007). These technologies "…are trying not to impose preconceived notions about how work should be categorised or structured.

Instead, they're building tools that let these aspects emerge." (McAfee, 2007) This means that there are no predefined roles, identities, or privileges; there are no workflow or process steps to follow; there are no specific data formats to adhere to, and there are no 'required' fields to fill out (McAfee, 2008).

One of our informants, IT coordinator for a large aerospace engine components manufacturer, highlighted: "We have a huge organisational memory of 80 years, but we do not have the possibility to search in it or retrieve it… When I do a new project, how can I use this information that is stored today? There are quite a lot of issues because they are stored in different systems and they are not presented in a way that engineers can use… I think we have locked the information too much by putting it in a document system like to die. Someone said that these traditional document systems are graveyards and I think they might have the point".

In our work in the aerospace domain, we have discussed that the 'context' of a specific engineering activity is constantly emerging. If we, for example, take six relevant context dimensions (product, activity, project, gate, role and discipline) into consideration, we can easily assume that engineers switch roles and projects as time goes by, and that different knowledge is needed at different gates and in different projects, etc. A challenge here is to make sure that just because the context dimensions might have been defined at one point in time, the knowledge attached to a certain context might be highly relevant in other contexts. If we can assist knowledge workers in contributing to a continuously emerging ‘folksonomy’ (Vander Wal, 2007), rather than merely adhering to a predefined taxonomy, we should be able to better support the serendipitous discovery of information or knowledge that we would not have discovered by traditional searches in the enterprise knowledge base. In the case of social bookmarking, people self-define their tags using words that mean something to them at the time, rather than categorising their bookmarks according to a predefined taxonomy. For example, a customer statement that is captured in the context of a request for a maintenance engineer, might be very interesting for an engineer working with concept development in the early phases of product development.

The absence of a predefined structure may also help in mitigating barriers to interoperability (Chen and Doumeingts, 2004), which characterises networked organisations. Traditional heavyweight systems are typically not designed for cross company collaboration and are difficult to integrate from a technological perspective, especially in a Virtual Enterprise situation. In the aerospace domain this issue is particularly evident: “…Regarding collaboration, we are pretty close to some OEMs with respect to be part of their IT solutions… this is very beneficial, but it is also a threat, because it easily makes us a victim of their system rather than developing our own methods and tools for what we need to do”.

Transition IV: From Lookup to Exploration

While it is always beneficial for knowledge workers to know where to get their facts checked and their questions answered, it is not merely the ‘Wikipedia effect’ we are striving for when discussing the potential benefits of a social software approach. We believe that one of the most promising aspects of such technologies is that they can help knowledge workers move beyond known-item searches, fact retrieval and question answering (Winograd, 2008). In the context of product development activities of the kind described earlier, it is highly interesting to assist knowledge workers in more exploratory and investigative activities, which are “…more concerned with recall (maximising the number of possibly relevant objects that are retrieved) than precision (minimising the number of possibly irrelevant objects that are retrieved).” (Marchionini, 2006, p.43).

This means being able to get the ‘full picture’ about a given problem before starting elaborating solutions able to provide the requested function. In the aerospace industry, for instance, the evolution of the passengers’ travel behaviour pushes the manufacturers to develop, manufacture and deliver products able to improve the perceived value for the end users through all the lifecycle. The dilemma for the engine manufacturers is to refine the ‘traditional’ engines, characterised by a lower cost of realisation but lowest lifecycle value contribution, vs. exploring advanced architectures capable of providing the full set of functionality required at aircraft level. The focus on value asks the designers to consider a wider range of issues and knowledge assets that would not have been considered in a traditional development situation: “If we would look only from a technical perspective we will always choose the first option. However, if we undertake the problem from a super-system and lifecycle-oriented perspective the second option is surely the best. We have a strong need to highlight dimensions not explicitly considered today in the preliminary design phase. We need to support ‘explorative’ design studies, we need to bring in more heterogeneous competences to support a value-based assessment.”

Moving away from the hardware-centric view of product development means that we must give engineers (and other actors throughout the value chain) opportunities for serendipitous knowledge discovery, where they can ‘stumble upon’ relevant knowledge, where they can browse a wide variety of topics that makes sense to others, and where they can gain a deeper understanding of what knowledge other people find useful and how they choose to deploy that knowledge.

Transition V: From Directional to Intersectional Innovation

Sir John Rose, chief executive of Rolls-Royce PLC, talks about how Rolls-Royce outsources and offshores about 75% to its global supply chain, keeping the 25% which are the "…differentiating elements…the hot end of the engine, the turbines, the compressors and fans and the alloys, and the aerodynamics of how they are made." (Friedman, 2005, p.459) Rose further notes that while companies are becoming increasingly specialised to meet market demands, this specialised knowledge will only address parts of any meaningful business or social challenge, which means that innovation comes from putting specialties together in new and different combinations (Friedman, 2005, p.457).

Johansson (2004, p.2) argues that companies need to step into the intersection of fields, disciplines and cultures to combine existing concepts into extraordinary new ideas, which implies that we need to harness the knowledge and intelligence of people who are not 'officially' on the team, who are not 'supposed' to have an opinion, and who are not 'familiar with' the specifics of the particular project. To us, this seems like an excellent pool of resources for innovation, if we can utilise it at a low overhead.

At Stanford University's 'd.school', this integration of perspectives is visible in their ambition to create 'T-shaped' people, who "maintain the depth and focus of a single discipline while adding a 'crossbar' of design thinking that drives the integration of multiple perspectives into solving real problems." (Winograd, 2008) The vertical part of the T represents depth in a particular discipline, and the horizontal part of the T represents a broader 'empathy' when it comes to respecting, valuing and embracing a diverse set of disciplines and perspectives.

Companies increasingly recognise the importance of building cross-functional teams to support the development of 'functions'. The identification of the right competence mix still remain a problem, with many companies exploring the use of social tools when it comes to locate the capabilities they need for establishing cross-functional efforts. One of our informants in the aerospace industry clearly highlighted this transition: "I see a great potential in social software when it comes to searching for the right competences, and finding the right people… We have previously tried 4-5 times to create a competence database where to store such information, forcing people to fill-in our forms, to indicate their skills, the project they worked on and such. It has been very hard to use. People felt that the system was too structured. They were forced to choose things that they didn't really felt matched, or things they did not want to deal with. Now we have a personal page were people are free to update information about themselves. I see that many users are taking time to add information and to make themselves visible throughout the company. If we could couple it with a good search engine it would be easier to find the right competences."

Transition VI: From Teams to Crowds

On the web, how many people that link to a particular page is an indicator of how 'good', 'interesting' or 'useful' that page is, but many corporate intranets do not allow their knowledge workers to create such links between the material they produce.

Since a VE is a highly distributed work environment, there is a problem of achieving critical mass in knowledge creation, sharing and discovery. While the number of knowledge workers in the enterprise might be very high, 'knowing who knows' (Larsson,

2005) is more difficult than before due to the fragmentation and distribution of knowledge across the enterprise. As noted before, intersectional innovation means that the notion of 'what a team is' has to be reconsidered.

Social product development implies that the innovation ecosystem of a VE includes "open and amorphous networks of peers" (Tapscott and Williams, 2006, p.257), where the people who contribute with knowledge might not be a part of the team or even the organisation, and where community-developed answers and ideas play a major part. If we consider the characteristics of functional product development in VE:s, we can actually see that some of the challenges of that context, i.e. related to diversity and distribution of knowledge workers, are turned into significant opportunities. To tap into the wisdom of crowds, you should keep social ties loose, keep yourself exposed to as many diverse sources as possible, and participate in groups that range across hierarchies. (Surowiecki, 2004) Engineering 2.0 technologies offer the potential to leverage on "…spontaneous and decentralised forms of mass collaboration" (Tapscott and Williams, 2006, p.259) in a self-organised way.

This is particularly true in a situation where the lifecycle 'value' of a solution is in focus rather than its pure technical performance. The latest aircraft development programmes give us the order of magnitude of such a transition: "Today when we start developing a new aircraft, we mainly listen to the airlines and to few other key stakeholders. The inputs coming from the 'environment', such as the organisation, user, customer, influencer, supplier, etc., are not formally considered and need to be made more 'visible' to the engineers, to understand the value of a design alternative...

We do not have detailed enough knowledge of what features the customers of our customers value the most, although they really care about the value that the product can provide them when they make the 'buying' decision… A challenge for us is to develop means to identify all the interesting stakeholders and customer segments and to tap into their knowledge to define the value creation drivers to develop our product alternatives."

Discussion

The research aims to develop decision support enablers for engineering teams working in networked and virtual environments. As shown in the empirical study, such teams are used to work with complex, multifaceted and ill-defined problems, and are asked to take decisions on the basis of missing information and ambiguous statements. Decisions, in fact, not only have to be taken even earlier than in the past to further reduce the time to market, but also encompass dimensions that fall outside the technical horizon of the engineers.

To cope with these shortcomings, individuals need to exchange information, advices and experiences with each other throughout the course of their work. The empirical study has shown that, although engineering processes are becoming more globally distributed and thus more reliant on information communication technologies, decision support tools do not yet adequately cover an important aspect of the decision making process: socialization. In the end of the day, individuals are those who take decisions, not the IT systems, which is methods and tools have to accommodate the need of the individuals engaged in the decision making process and not vice-versa. This encompasses coping with communication and socialisation problems in the quest for envisioning solutions to design problems.

Who are these individuals then? How do they approach problems and how do they search for solutions? Looking at the job market, many acknowledge a remarkable generational shift to happen in the next few years. A new, young generation of engineers is soon coming into the melting pot; they are often described as belonging to the so-called Generation Y (Eisner 2005). Generation Y is composed of people born between 1980 to 1990 who has very different characteristics from their predecessors, Generation X and the baby boom generation. A main difference concerns the use of information technologies. Generation Y is born with Internet and individuals have grown up in a world with limitless info at their fingertips. This makes younger employees more multitasking than their fathers, in general more acquainted with information technologies and ready to exploit the capabilities provided by social tools and Web 2.0.

Generation Y is more distributed, digital, cultural diverse and participatory than the older ones. Engineering culture, which changes slowly in established firms, is struggling to adapt to the relatively rapid changes of methods and workforce. In this sense, organizations, especially when working in networked and virtual environments, must learn to utilize technical talent in more open and collaborative ways. In the same way, companies need to reconsider their decision support methods and tools when addressing such new type of individuals.

The paper aims to contribute to the discussion about the development of effective decision-making support in the light of such upcoming changes. The six transitions described point towards aspects that need to be considered in the development of such enablers, both to meet the challenges brought by cross-functional and cross-organizational design environments, and to capture the energy and enthusiasm of the people that are going to use them.

The research is currently exploring different ways to support socialization processes by means of Web 2.0 mechanisms, ranging from the use of blogs, wikis, microblogs and video platforms to facilitate conversational knowledge capturing and sharing in industrial environments. On the authors' advice, integrating social functionalities in the existing decision support systems will foster the design team's capabilities to discover, share and use knowledge assets created in a wide variety of domains (e.g., product development, opportunity management, sales, aftermarket) and organizations. For product development processes this will mean reducing the product lead-time, effort and rework by improving the quality of early design decisions through encouraging radical innovations (providing more 'stimuli' to guide concept generation), shortening routine tasks (reducing the time needed to identify relevant knowledge) and lowering the threshold for documenting rationale, best practices and lessons learned across projects.

Conclusions

Social product development is on the rise. On one end, the starting position for product development activities in the virtual organisation consists of people from different functions and companies that do not have a previous history of working together. There are no 'shared assumptions' about how to collaborate within the team and no 'shared vision' for what to develop. On the other end, engineering is moving even more back and forth between 'problem solving' and 'prediction'. Engineers struggle to collaboratively figure out how to approach ill-defined problems and, in cases where it is just not possible to reach an agreeable solution, they need to make well-founded predictions about what a solution might look like in the future. Hence, the ability to seamlessly assemble and utilise the capabilities of the networked partners in new product development projects is crucial for successful product development initiatives.

The empirical study has showed that 'heavy-weight' systems need to be complemented by more social and lightweight systems, better equipped to enable an open, bottom-up, collective sense-making approach to knowledge sharing. Although a somewhat controlled, top-down, approach plays a strong role in virtual enterprise collaboration – and thus is common in current industry practices – it is not sufficient to cope with the issues triggered by the increased virtualisation of product development activities.

A major benefit of social technologies is that they allow shared assumptions - about how to do the job; who does them; how coordination is done - to be developed through folksonomies and other decentralised, bottom-up approaches, paying closer attention to what documents, data, photos, and stories really mean to people, as opposed to the way they are encapsulated in corporate taxonomies and databases.

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