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Abstract

In light of emerging product development trends, such as Product-Service Systems, manufacturing organizations are obliged to collaborate across functional and organizational borders. Hence, companies are increasingly investigating how to leverage knowledge management practices to enhance their dynamic learning capabilities to achieve continuous process improvements. Many researchers assert that lessons learned practices are possible ways for organizational learning, which allows for continuous capturing and sharing of experiential knowledge across boundaries in order to learn both from mistakes and successes. However, many organizations fall short in capturing and sharing lessons from projects and applying them in new situations. The purpose of this paper is to propose a video-based approach and related guidelines for capturing and sharing lessons learned in a dynamic manner across functional and organizational boundaries. Based on laboratory experiments as well as validation activities conducted in collaboration with an aerospace manufacturer, this paper compares the video-based approach with a more traditional text-based approach of documenting lessons learned from projects. The paper describes the results of testing activities conducted with a video-based lessons learned prototype and the authors reflect on its implications for design practice management in the aerospace industry.

Keywords: Lessons learned, Lessons learned template, Experience sharing, Web 2.0, Video sharing, Knowledge management, Organizational learning, Product-Service Systems.

1 Introduction

To compete in the dynamic global economy, traditional product-oriented companies are searching for new ways to differentiate their market offerings and to create unique value for the customers (Shaw and Ivins, 2002). In business propositions such as Product-Service Systems (PSS) (Mont 2002), the manufacturing companies offer 'functions' or 'results' instead of mere hardware, retaining ownership and responsibility for the product throughout its entire lifecycle. For instance, aero-engine manufacturer Rolls-Royce offer 'TotalCare®' packages (Harrison 2006) to its customers, long-term business agreements centered on the provision of a function (i.e., 'Power-by-the-hour') instead of an aero-engine. Development teams are therefore urged to design products and services in a more harmonised way, being aware of those properties governing the lifecycle behavior of the hardware since an early phase (Isaksson, Larsson & Rönnbäck 2009). This requires accessing a wide range of skills, knowledge and expertise from different functional domains (Larsson et al. 2008), such as from mechanical design, electrical engineering, computer science, aerodynamics, material science, manufacturing, operations, maintenance, and service engineering. This new scenario emphasizes the need to extend continuous learning beyond functional and organizational boundaries (Cooke-Davis 2002) and to enhance dynamic learning capabilities to achieve continuous process improvements (Baria 2005).

As observed by several researchers (Kotnour 2000; Milton 2010; Tan et al. 2006), capturing and disseminating lessons learned from the projects lowers the barriers to organizational learning and knowledge sharing. However, today's corporate culture is not very conducive for cross-team learning (Carrillo 2005; Dixon 2004), causing learning opportunities to be missed. Lessons learned processes are often limited to a 'single department', a 'single business unit' or to 'specific projects' (Thompson 2005; Williams 2008), and databases are difficult to search, further lacking support for knowledge reuse (Marlin 2008). Furthermore, 80% of organizational knowledge is stored in people's heads, 16% is semi-structured and only 4% is formalized as structured data (Bell 2006). Most of the 'working knowledge' (Davenport and Prusak, 1998), or 'knowing in practice' (Orlikowski 2002) in organizations is therefore tacit (Nonaka and Takeuchi, 1995; Polanyi 1967) and not in a readily available form for PSS developers.

Organizational, cultural, methodological and technological support is needed to facilitate cross-team learning across boundaries. This is particularly evident in PSS development, where the need for a more open, bottom-up, and "lightweight" (Bertoni, Chirumalla & Johansson 2012; Larsson et al. 2008) knowledge sharing support is emphasized. The purpose of this study is, therefore, to answer the following research question: *How to lower the threshold for capturing and sharing lessons learned across functional and organizational boundaries?* In this perspective, social computing and Web 2.0 technologies look particularly interesting to enable the sharing of individual/team 'tacit' knowledge or 'knowing in practice', as well as to improve communication in boundary-crossing collaborative environments (Levy 2009; Lytras, Damiani & de Pablos 2008; McAfee 2006). Accordingly, the objective of the paper is to propose a lightweight knowledge sharing approach – based on video technologies – for capturing and sharing lessons learned across organizational boundaries in a dynamic manner. The paper details the methodological and technological enablers, describing the results of preliminary verification activities.

2 Research Approach

The research, which is mainly qualitative in nature (Yin 2009), is framed according to the Design Research Methodology (DRM) (Blessing and Chakrabarti, 2009) and consists of four main phases: *Research Clarification*, *Descriptive Study I*, *Prescriptive Study*, and *Descriptive Study II*. This paper is a main outcome of the *Descriptive Study II* phase. Empirical data in the descriptive phases have been collected from development projects in the aerospace and manufacturing tools industry, mainly focusing on how companies use various knowledge management (KM) systems to capture and disseminate experiential knowledge in their regular working activities. The data gathering activities were performed at the companies' facilities between May 2009 and June 2011, and entail 17 structured/unstructured interviews (Fontana and Frey, 1994), 3 focus groups and 3 virtual meetings. Such data were complemented by 15 survey questionnaires. These initial findings have been summarized using the Strengths-Weaknesses-Opportunities-Threats (SWOT) as a framework, which describes the enabling capabilities of Web 2.0 technologies for cross-functional knowledge sharing in early PSS design (Bertoni, Chirumalla & Johansson 2012). The SWOT has highlighted the importance of using Web 2.0 technologies for sharing lessons learned in a continuous manner across functions and organizations. Embarking from a theoretical review of lessons learned, descriptive study II was started on August 2011, focusing on design practice support systems for the aerospace sector.

The design practice (DP) documents specific technical realisation instructions for each product design. As observed in the study, DP lacks support for recording experiential knowledge from past projects, especially concerning lessons learned from the downstream processes. Empirical data on DP-specific issues were collected through 10 interviews with system owners, project leaders, managers, company specialists, chief engineers, and quality assurance leaders. The findings have brought definition to the topics/steps and guidelines for structuring lessons learned, and have highlighted videos as a preferred means for capturing and sharing. Methodological and technological enablers were further developed and tested in a laboratory environment by researchers and practitioners with experience in product development projects. Small scale experiments were initially conducted to understand the underlying mechanisms related to the capture and reuse of lessons learned using videos. In a second phase, topics and guidelines were refined and tested in design sessions with researchers and students in the Product Development Master Programme at Luleå University of Technology, involving 25 participants. The test aimed both at verifying the "lightweightness" of the approach for non-expert users and the possibility to reuse the lessons in new problem contexts. Testing activities were further conducted at the companies' facilities to verify the integration with the DP system. A selected number of stakeholders were asked to record lessons learned videos related to design practices from past projects. The findings from such verification activities are presented in the later sections of the paper.

3 Literature Review

3.1 Lessons Learned

Product development is a knowledge intensive activity, where experiential knowledge is shared across time and space (Buttler et al. 2011) from one project to another to support decision-making. Problems are seen in the way experiential knowledge is contextualized in real work activities (Kerr, Waterson & Clegg 2001) as well as in that knowledge's tacit nature (Polanyi 1967). Most of the knowledge acquisition activities in organizations occur in an informal manner, mainly through day-to-day social interactions with colleagues and with established networks of contacts (Kerr, Waterson & Clegg 2001; Larsson et al. 2008). Nonaka and Takeuchi (1995) describe this phenomenon of organizational learning in organizations as a SECI model. SECI depicts four modes of knowledge conversion, namely: tacit to tacit (socialization), tacit to explicit (externalization), explicit to explicit (combination) and explicit to tacit (internalization). Accordingly, tacit knowledge is made explicit so that it can be shared, combined, and then internalized by applying it in new practical situations. Researchers claim that metaphors and stories give the richest opportunities for articulating and sharing tacit knowledge (Buttler et al. 2011; Swap et al. 2001) and for supporting transfer of experiential design knowledge and design rationale (Erickson 1995). Several researchers emphasize that capturing lessons learned stories from the projects is a way to stimulate sharing these experiences (Buttler et al. 2011; Goffin et al. 2010). Lessons learned (LL) are knowledge artifacts that convey experiential knowledge derived from success or failure of a task, decision, or process, that when reused, can positively impact an organization's performance (Weber, Aha & Becerra-Fernandez 2001). Many organizations in a variety of sectors (e.g., military, energy, construction, and government) have deployed LL processes and systems to prevent the 're-invention of the wheel' and to avoid repetition of previous mistakes (Baria 2005; Carrillo 2005; Milton 2010; Weber, Aha & Becerra-Fernandez 2001). LL practice was the outcome of after action reviews, which were introduced by the US Army in the mid-1970s (Weber, Aha & Becerra-Fernandez 2001). Since then, the concept has been adopted in a number of organizations under a number of different names, such as post-project reviews, project postmortem review, reflection, debriefing, corporate feedback cycle, reuse planning, and cooperative project evaluation (Disterer 2002). Major issues with post-project reviews (e.g., Goffin et al. 2010; Kamara et al. 2003) refer to staff turnover, reassignment of people to the new projects and the time lapses in knowledge capturing. Based on a survey of organizations that deploy and utilize LL systems, Weber et al. (2001) not only found that LL systems poorly serve their intended goal of promoting knowledge sharing and reuse, but also identified the essential components of a generic LL process to be: *collect*, *verify*, *store*, *disseminate*, and *reuse.* A major concern is that lessons are described as a set of free-text fields within a system and the systems are typically not integrated into an organization's decision-making process. To address these limitations, Kumara et al. (2003) and Tan et al. (2006) propose a methodology for 'live' capture and reuse of project knowledge, by using a template featuring background information on the project, abstract, conditions for reuse, relevant details and references.

3.2 Web 2.0 and Enterprise 2.0

The term "Web 2.0" describes a significant move in the way people create, store, edit, access, share and distribute content on the World Wide Web (O'Reilly 2005), changing the way people interact (Levy 2009; McAfee 2006). Examples of Web 2.0 applications include blogs, wikis, social networking, tagging, RSS feeds, mashups, social bookmarking micro-blogs, media sharing, web applications and podcasting (McAfee 2006; O'Reilly 2005; Parameswaran and Whinston, 2007). Anderson (2007) proposes six drivers to explain the Web 2.0 phenomenon: (1) Individual production and user generated content, (2) Harnessing the power of the crowd, (3) Data on an epic scale, (4) Architecture of Participation, (5) Network Effects, and (6) Openness. Chatti et al. (2007) propose Web 2.0 driven SECI model learning process, based on Nonaka's SECI approach, which combine formal/informal learning, knowledge management, and Web 2.0 concepts into one integrated solution for a model of network learning through active participation in different communities. McAfee (2006) further pointed out the rising company interest in Web 2.0 with the term "Enterprise 2.0". He summarizes the underlying components of Enterprise 2.0 technologies with the acronym SLATES (Search, Links, Authoring, Tags, Extensions and Signals) (McAfee, 2006). Web 2.0 in enterprises has its largest impact on knowledge work, innovation processes and cooperation (Fuchs-Kittowski et al. 2009), facilitating knowledge transfer in complex engineering environments (Murphy and Salomone, 2010) in relation to two key knowledge management strategies - namely, personalization and codification (Hansen, Nohria & Tierney 1999). From an engineering point of view, Larsson et al. (2008) have coined the term "Engineering 2.0" to describe customized and ad-hoc Web 2.0 applications able to support engineering product development in an extended enterprise setting.

3.3 Video Sharing

Video sharing is one of the most adopted Web 2.0 technologies in companies (i.e., top 3 with 38%) (Bughin, Byers & Chui 2011). It is especially useful for scanning the external environment, finding new ideas, and managing projects. Video has also been recognised as a useful medium to support design activities (Harrison et al. 1989). Harrison et al. (1989) found videos to be a well-suited medium for supporting design communication processes, as videos are experiential and involving in nature - not detached and compartmentalized like text. In many disciplines, researchers have been using videos to capture subtle and complex aspects of performed activities and to represent overviews of key dynamic processes (Leon 2005; Wood, Rust & Horne 2009; Zender, Schwehm & Wilke 2006). In ethnographic field studies, it is often termed “video-ethnography” (Leon 2005). Web 2.0-enabled capabilities facilitate video hosting services, which could allow individuals to upload video clips to Internet websites to capture and communicate stories with a richer and more dynamic content (Cha et al. 2007; Parameswaran and Whinston, 2007). Additionally, Web 2.0 offers annotations, tagging, bookmarking, commenting, editing, and ranking functionalities to increase the ability to share, network, find and discuss videos across dispersed boundaries. Wood et al. (2009) investigated using videos to elicit and transmit the tacit nature of skilled practices, such as crafting knives. They created a web-based learning resource for novice craft practitioners, which offered a more flexible way of developing and refining their crafting skills (Wood, Rust & Horne 2009). From a lessons learned system point of view, Shariff et al. (2005) added features to lessons learned systems to allow users to upload media files, such as pictures and videos, to support a socialization process. Similarly, Xerox technicians are using media attachments to further promote lessons reuse (Weber, Aha & Becerra-Fernandez 2001). Further, Zender et al. (2006) developed a video approach to knowledge management, documenting operational procedures and preserving individual/group experiences during space applications development. At present, however, there is little evidence available in literature on using videos with Web 2.0 capabilities as a medium for continuous capturing and sharing lessons learned across boundaries within the product development domain.

4 Method for Capturing and Sharing Lessons Learned Videos

The preliminary experimental results identified that videos are beneficial for capturing lessons learned (LL) as they can capture the context of dynamic problem situations and that reduces time-consuming manual processes while capturing lessons in a continuous manner compared to a more traditional text-based approach of documenting LL. However, capturing an LL video is not merely about making a video with some stories from a project. The LL video must be factual, technically correct, valid and applicable to specific tasks, processes and decisions. Hence, the authors have developed a method for capturing LL videos as a means to provide the structure and to lower the threshold for the people who want to share their lessons.

4.1 Description of the lessons learned capturing template

Both laboratory experiments and industrial case study observations (hereafter referred to as the “empirical study”) highlighted the need to structure the lessons learned (LL) videos in seven steps. These steps are: *lesson learned statement*, *working context*, *task description*, *what went wrong* or *what went well*, *lesson learned*, *lesson learned measures*, and *applicability & delimitations*. Each step has a set of guiding questions to support the users in formulating their message in a clear, concise, and informative manner for each section of the LL video as shown in Table 1.

The section below follows short descriptions and rationale for each step of the LL template:

0 - Lesson learned statement: The empirical study showed that it is important to provide the user with a quick summary of the lessons learned to shortly recapitulate the main points about its contents to explain why it is important. This tends to be a brief statement introducing the topic to knowledge seekers in a shorter sentence as a caption or title of the LL video. In this way, LLs statements can enhance browsing capabilities for the user to quickly go through several knowledge elements and thus find the right LLs faster. Hence, this step is considered as “0” in a lesson learned story.

1 - Working context: The empirical study showed that users need to understand the background and working situation of the task that the LL concerns. This includes person name, job role, project name, component/product, and operational level within the phases of global product development process, and a list of stakeholders involved during the task. On the one hand, this information provides the background and allows the knowledge seekers to decide if it is a relevant video or not. On the other hand, this information intends to guide the knowledge seekers to identify whom are relevant experts and stakeholders specific to the performed task, for instance, ‘knowing who knows what’ or ‘knowing whom to ask’. In this way, the users can benefit from seeing the people involved in the task and add more emotional impact compared to the text-based approaches.

2 - Task description: The empirical study showed that the users are benefited from a short description of the task the LL concerns. Descriptions include how the task was executed and what the conditions and circumstances where it was operated were, as well as what key parameters or tools were used.

3 - What went wrong or what went well: The empirical study showed that it is important to clearly describe the learning from successes or failures that came across during activity. It is therefore possible to pinpoint where—and how—the problem/favorable outcome occurred as well as what the effects were on task execution or project. This information works as a ”know-why” explanation for the lesson learned where knowledge seekers can learn about either avoiding the same mistake again or repeating a successful outcome.

4 - Lesson learned: The empirical study showed users need to be provided with a detailed description of the lesson was learned, recognizing the new or improved solution to avoid the problem or to repeat the favorable outcome including any additional experiences. At this point each lessons learned focus should be on what was learned that would benefit the performance of a future activity or project.

5 - Lesson learned measures: The empirical study showed that it is important to describe how effective the lesson learned was on the process, for instance by measuring the performance of an improvement. The users should provide some quantifiable measurements of change (e.g., time, cost, quality) in the process by comparing the performance with previous conditions. This information can increase the credibility of the lessons learned reuse by knowledge seekers.

6 - Applicability & delimitations: The empirical study showed that it is important to describe the applicability of the LL in terms of tasks and projects. The user identifies, for instance, who are the potential beneficiaries (or target audience) of the LL, and where it can be applicable. This information can help the knowledge seeker to decide on whether s/he makes use of the LL and to avoid wasting time on LLs that are not applicable to them. Users should also offer advice on limitations of their LLs by providing information, such as the amount of analysis and scrutiny it has undergone, what additional activities are necessary for further validation, and how it can be institutionalized smoothly. Though this information is based on personal experience and gut feeling, it plays a crucial role to create a reciprocal cross-team learning environment across boundaries.

4.2 The process for capturing, sharing and validating LL videos

The study has taken a lesson learned (LL) process view, similar to Weber et al. (2001), to test and validate the video-based approach in laboratory and industrial environments. The video-based LL process consists of six stages, including:

1. *Identifying the LL during an activity*: The LLs can be identified by the individual people in day-to-day activities or by the project team in the stage-gate process (Cooper 2008).

2. *Preparing and formulate an LL story using the steps and guidelines in the above LL template*: The guidelines in the template are prepared in a way to make sure that the outcome will be the “richer” description as a story. The “notes” column in Table 1 is left blank intentionally to show that LL contributors take the template and prepare their lesson learned story using the template.

3. *Recording the LL video, storing and sharing with proposed tags and secrecy settings*: The LL contributor records the LL video and proposes several tags on the basis of, for instance, the applicability for other activities/projects to make the LLs searchable. Further, contributors can propose the name of a validator or specialist in the LL area for approving their LL video in a rapid manner. Additionally, the contributors can propose a “secrecy level” to their LL from scales 1 to 4 to enhance privacy and confidentiality for sharing sensitive lessons from the projects across boundaries.

4. *Validating and disseminating the LL with secrecy and tags settings*: Following the LL contributor request for approval of their LL video, the proposed validator gets the alert message to review the LL.

The validator can go through with the dissemination settings proposed by the LL contributor and approve it with minor or major changes. Derived from the inherently secretive nature of aerospace engineering working culture, the empirical study highlighted the vital role of this validation part in disseminating the lessons from the projects.

5. *Searching and retrieving the LLs using the tags*: The knowledge seekers search for the LL videos based on the tags defined in the system. From the empirical study, it was found that LL videos codified with tagging functionalities could make it easier for knowledge seekers to search and retrieve the lessons that are tagged in the same way from different functional and organizational boundaries.

6. *Reusing the LLs in new activities*: The empirical study showed that the video sharing approach to LLs could allow cross-functional teams to add their reflections, comments and rankings after their usage of LLs.

<Proposed video-based approach for capturing lessons learned stories>

No	Steps	Guidelines	Notes
0	Lesson Learned Statement	Shortly summarize the main points about this lesson and why it is important for others to know.	
1	Working Context	**Describe the background of the task:** Name of person, job role, product type and project name? What is the operational level of the task within the product development process? Who are the stakeholders (internal/external) connected to the task?	
2	Task Description	**Briefly describe the task:** How was the task planned and executed? What key parameters or tools were used? What are the conditions and circumstances when the task was executed?	
3	What Went Wrong or Well?	**Describe problems/successes that you came across during the activity:** What was the problem/favorable outcome? Where did you identify the problem(s)/favorable outcome? How did you identify the problem/favorable outcome? What is the effect of the problem(s)/success on task execution?	
4	Lesson Learned	**Describe the lesson that you learned:** What are the root-causes of problem/success? What steps have you undertaken to solve the problem or to find the success? How can the problem be avoided or how can the success be repeated? What is the recognized new or improved solution to avoid the problem or to repeat the favorable outcome?	
5	Lesson Learned Measures	**Describe the measures to the improved solution of the problem(s):** How can your lesson learned improve the problem area or success area? How would you quantify the change/improvement compare it with pre-existing solutions?	
6	Applicability & Delimitations	**Describe the applicability or delimitations of the lesson learned:** Who are the potential beneficiaries of your lesson? Where can the lesson be applicable? How it can be 'institutionalized'? What is the level of quality of LL information? What additional activities (i.e., verification, validation etc.) are necessary? What are the limitations of your lesson?	

Table 1. Layout of LL capturing template in the proposed video-based approach

4.3 Technological enablers for capturing and sharing LL videos

Different video capturing equipment was tested during early verification activities, varying among professional HD cameras, webcams and mobile phone cameras. YouTube® (www.youtube.com) has served as a video repository during the first round of experiments and as a platform for testing basic tagging and annotation functionalities. A number of other video hosting services have been further analyzed to identify functionalities able to cope with the needs emergent from the empirical study. These include annotating, tagging, editing, commenting, bookmarking, ranking/rating, aggregating, embedding and filtering/grouping functionalities. Based on the gathered user needs, all the required features were drawn and mapped against the list of functionalities. Eventually, this led to the mock-up of video-based LL sharing platform with the following interfaces shown in Figure 1.

As seen in Figure 1, the LL video displays annotations of LL template topics/steps as an overlay on top of the video and might also include information about their duration. The researchers' observations showed that this way of representing the LL videos allows the knowledge seekers to see a visual display of how the lesson learned story has been structured and captured in the video. Moreover, users can browse for interesting topics of LL instead of going through whole video. Additionally, the experimental observation also considered having "browsing points" on the video status bar, which symbolize the seven topics in the captured lesson-learned story. The empirical observations revealed that these capabilities built on top of the LL video could allow the users to browse and absorb many LL videos in a shorter time span. In this way, the new video-based approach improves the accessibility of browsing LLs compared to the text-based approach. In addition, the proposed features enable users to examine the individual relevant LL topics rather than displaying complete videos, and hence improve the 'searchability' and 'retrievability' in channeling relevant LLs to the knowledge seekers. For instance, if a stress analysis engineer is looking for "What went wrong" in the simulations from previous projects, the platform can compile and display all the related "what went wrong" issues specific to analysis engineers. The case study highlights the special needs in a PSS context, where users can quickly add LL videos to the product lifecycle timeline in alignment with the DP system. Such practice can help continuous capturing and disseminating of the lessons learned from the downstream processes, which could help the cross-organizational teams accessing properties governing lifecycle behavior in the early conceptual stage. The empirical observations highlighted several bookmark links to be considered in the platform, including, but not limited to, "share", "validator" and "secrecy level". The "Share" bookmark link can facilitate an LL contributor to quickly add video clips to the project portal, intranet, functional group sites, and project blogs, and so on. The "Validator" bookmark link can help an LL contributor to identify the relevant experts on the concerned LL topic, discipline and area of relevance. The "Secrecy level" bookmark link can allow an LL contributor to decide on accessibility control of the different video sections depending on the secrecy of the LL content, and thus let only some categories of users access the entire video, while others will have access to only a part of it. Based on the case observation, the study identified 4 secrecy levels, namely: product function group, internal organization, open to other business units, and suppliers, as shown in Figure 1. In the illustrated scenario where the knowledge seeker belongs to a subsidiary of the main company, information related, for instance, to Working Context, What Went Wrong/Well and Lessons Learned Measures might be hidden due to the risk of knowledge leakage. In such a situation, only a limited part of the video is going to be accessible and available for review. The development of the necessary technological support to enable such a scenario is part of the research and it is currently ongoing.

Further, the study considered another important 'social' and 'bottom-up' capability of Web 2.0—social tagging—where users could collaboratively classify and index the LL videos based on the proposed tags as shown in Figure 1. Another technology enabler for developing social ties across organization is to leverage conversations around LL videos. The empirical study considered specific commenting functionalities related to the LL videos, where other people in the organizations go through the video and add their relevant comments specifically to the topics of the LL story, as shown in Figure 1. The other users can then go through with these comments and rank them based on applicability and dependability. In addition, the mock-up considered "like," rating, follow the user and "embed" social features in the platform in order to enhance the bottom-up and social networking capabilities. Based on preliminary experiments, the LL video-based approach, in this way, can capture the context of complex situations, and leverage cross-functional sharing and networking across organizational boundaries.

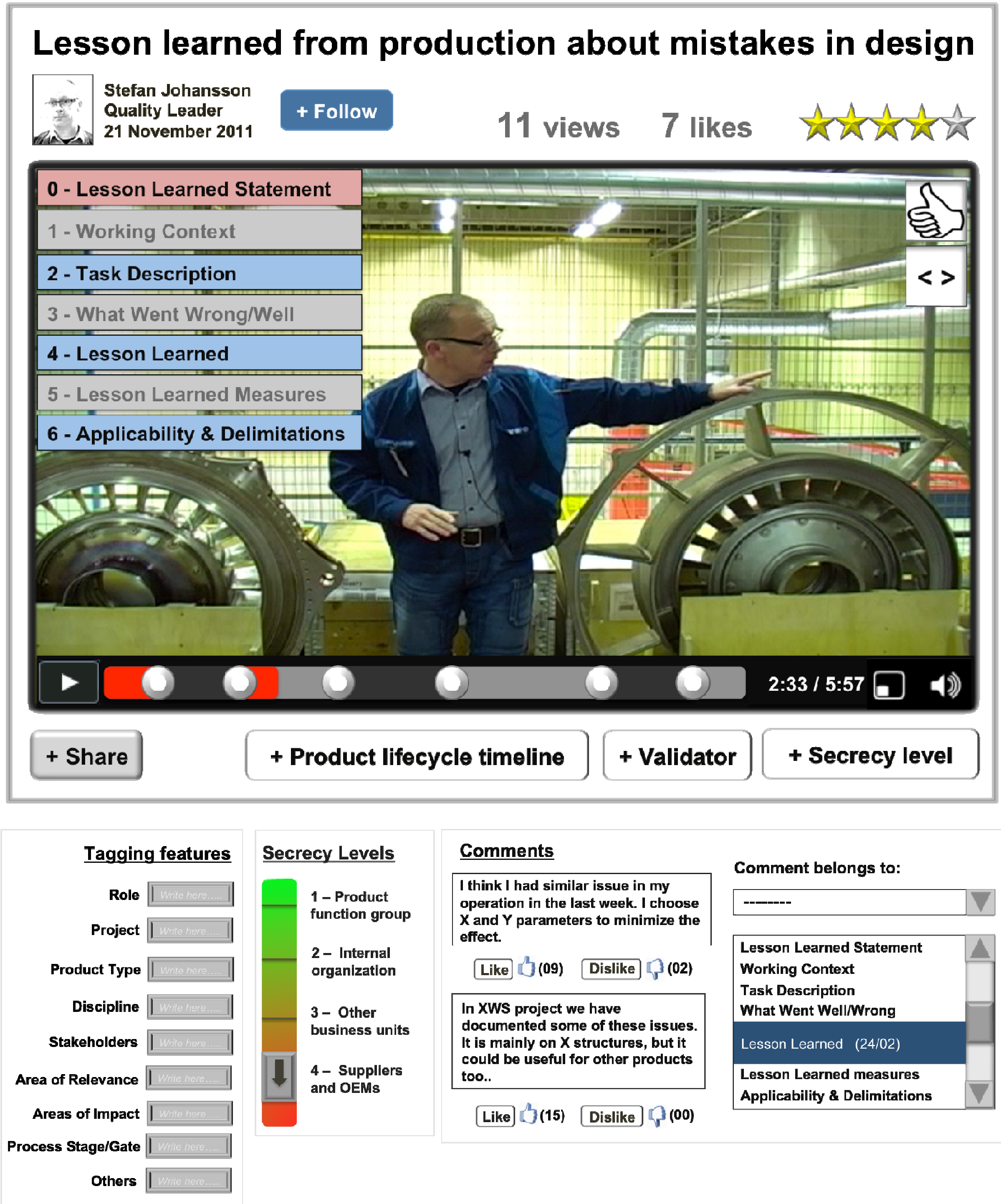

Figure 1. Video-based LL sharing prototype platform with functional interfaces of tagging, commenting and secrecy levels for enabling cross-functional knowledge sharing

5 Discussion

In a PSS early phase, engineers have to use experiential knowledge to decide on how the provision of a function has to be solved technically. Simulation models should, in fact, emphasize operational aspects, that often refer to the individual's own experience with the product. The study findings confirm that such knowledge is rarely captured in a codified form using post-project text-based approaches; rather it is stored only in the mind of individuals and exchanged through informal discussions and story telling (Buttler et al. 2011; Goffin et al. 2010). Although stories allow people to share experiential knowledge more effectively, they are rarely captured in a homogenous and continuous way in the industrial context studied. Several ad-hoc formats and recording practices have been observed, making it difficult for the PSS team to identify and contextualize such lessons. Text-based approaches mostly lack contextual "richness" and are too high-threshold for some users to regularly document their activities. For these reasons, Web 2.0-enabled videos have emerged as a preferred means for sharing stories and lessons in a virtual enterprise environment. To some extent, the approach resembles Case-Based Reasoning (CBR) (Weber, Aha & Becerra-Fernandez 2001) in its aim to lower the effort in capturing and displaying knowledge, as compared to a rule-based system.

The approach is based on a 7-step template, which is intended to facilitate the capturing of contextual information compared to what is already available in literature. Preliminary verification activities have shown such a solution improves the preparation and formulation of stories compared to other traditional templates and recording means. Most of the respondents stated that videos are more suitable for explaining why certain decisions were made, and to record the rationale for a given solution strategy. They also allow picturing downstream processes with more details, such as production or maintenance activities' flow. Eventually, the approach was found to lower the threshold for capturing knowledge from skill-oriented activities, such as laser welding or servicing operations.

From PSS perspective, the approach presented in the paper represents a step forward toward supporting a way of articulating and making tacit knowledge available, for the benefit of the design activity. The industrial discussion has also highlighted the possibility to integrate videos with other Web 2.0 tools. For instance, the stories could be synthesized in a wiki page to provide novice engineers or newcomers an easy to use knowledge base, from which to grow their knowledge in new projects. Web 2.0 mechanisms, in fact, can foster a more collaborative approach in LL capturing and sharing. For instance, social tagging capabilities could make videos with similar tags more discoverable across functions. As a side effect, this can help the PSS designers in fostering their weak ties, highlighting hidden experts and communities interested in discussing certain aspects of the product across the organizational containers. Feedback mechanisms (such as: likes, rating, number of views, comments or bookmarks) can help in raising the engineers awareness of topics particularly "hot" in the later lifecycle phases, and that can influence the design of the hardware – or the software and service part. Eventually, PSS designers might be able to ground early decisions on a more solid base, being aware of behavioral aspects of the PSS in operation that are not easy to represent with traditional knowledge management tools.

6 Conclusions and Future work

This paper has proposed a video-based approach for capturing and disseminating lessons learned practices in a dynamic manner across functional and organizational boundaries. With respect to complex PSS development projects, where the hardware, software and service knowledge is distributed across functional and organizational boundaries, Web 2.0 enabled video-based systems can facilitate the sharing of experiential knowledge in forms of lessons learned among knowledge workers. The present study focuses mostly on methodological issues about "why and how" using videos to record lessons learned relevant for early PSS activities. Hence, this study limits its focus on the details of the technological enablers to develop specifications for a technology. In the future, the study will extend to the development of a full-scale prototype system, using open-source video sharing applications. The prototype will serve the purpose of testing the viability and performances of approach by experimental means, observing and analysing through a range of experiments how Web 2.0 mechanisms can support lessons learned sharing across organizational boundaries in a PSS context. A set of experiments will be designed and conducted to compare traditional and Web 2.0-based knowledge management systems on how they leverage a cross-functional team's ability to capture knowledge from heterogeneous functions, to increase awareness about knowledge owners and knowledge sources and to increase confidence and participation of new comers in design practices.

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