USING VIDEOS TO RECORD LESSONS LEARNED FROM PRODUCTION AND AFTERMARKET PHASES: PRELIMINARY RESULTS

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Abstract: Learning from experience has turn out to be the basis of every manufacturing company in creating and sustaining competitive differentiation. Many companies put effort in capitalizing these experiences through continuous improvement initiatives such as lessons learned practices. However, these practices are failed to address the distinct, complex settings available in manufacturing, serial production, use, and maintenance phases, where much of the learning is still tacit nature and difficult to articulate. In this context, based on three case studies in the aerospace industry, the author previously proposed a lesson learned methodology using videos as an enabling media. This paper presents some preliminary results based on the validation activities performed in the aero-engine component manufacturing company.

Keywords: Lessons learned, capturing knowledge, tacit knowledge, experience feedback, knowledge management.

1. INTRODUCTION

In today's rapidly changing business environment, companies are under constant pressure to produce products of increased quality, reliability and performance, while reducing time-to-market, development costs, and risks. Learning from experience is increasingly acknowledged as one of the ways to achieve the above-mentioned targets (Thomke and Fujimoto, 2000). When it comes to product development, experiences made in the manufacturing, serial production, use and maintenance phases of a product lifecycle are critical sources for learning (Andersson, 2011; Goh and McMahon, 2009).

Many industrial product development procedures already comprise an integrated planning of product and production processes. The integrated product and production development implies a different way of running development projects compared to traditional sequential projects (Bellgran and Säfsten, 2010), where accessing and employing past experiences from manufacturing, serial production, and aftermarket phases play a crucial role.

Moreover, in recent years many manufacturing companies have been shifting their strategic focus from selling a physical product to selling its performance or availability (Baines, et al., 2007). In such cases customers pay only for the provision of usage of a product and the manufacturer retains ownership of it and is responsible for servicing and maintaining it throughout its entire lifecycle. In this setting, learnings from aftermarket phases of similar products are becoming crucial to improve the design and manufacture of the new products and associated services (Masood, et al., 2014). Thus, in the light of emerging product development trends, learning lessons from experience of existing products is becoming even more important.

Many manufacturing companies have established continuous process improvement initiatives, such as lessons learned practice, to capitalize on past experiences (Andersson, 2011). The goal of these initiatives is to improve abilities of the organization in identifying and capturing lessons learned from production and aftermarket phases, and bringing those to early development phases for improving next-generation products. However, many organizations are struggling with the collection and dissemination of lessons, which greatly hinders the attainment of potential benefits from LL practices (Milton, 2010; Williams, 2008). Milton (2010) found that 60% of 74 examined organizations that attempted to implement LL processes were dissatisfied because lessons were identified and captured but often not followed through and applied internally to deliver the intended changes in personal or organizational behavior, processes, best practices or standards.

The current literature presented mix of several LL approaches from different disciplines. However, the current approaches are failed to address the distinct, complex settings available in manufacturing, serial production, use, and maintenance phases where much of the activities to a greater extent is skill-oriented activities, in which much of the learning is still tacit nature and difficult to articulate. One of the most common kinds of LL sessions are post-project reviews or postmortems, but their effectiveness for leveraging tacit knowledge has been widely questioned (Goffin, et al., 2010; Milton, 2010; Tan, et al., 2006; Williams, 2008). Thus, there is a lack of practical methods and tools for capturing LL related to tacit knowledge from skill-oriented activities. In addition, there has been little research conducted on LL practice in production and aftermarket phases such as use, maintenance and end-of-life.

In this context, the author previously proposed a new methodology for capturing lessons learned from production and aftermarket phases (Chirumalla, 2013). The methodology represents a lesson learned in a standardized format together with guidelines, using videos as enabling media. The purpose of this paper is to present and discuss some preliminary results of validating methodology in the aero-engine component manufacturing company.

2. THEORETICAL FRAMEWORK

This section introduces the theoretical basis for this study, which includes the following areas such as type of knowledge, lessons learned, and video recordings.

2.1. Type of Knowledge

Knowledge represents information combined with context, insight, and reflection (Alavi and Leidner, 2001). One of the most common distinguishes of knowledge is between explicit knowledge and tacit knowledge (Nonaka 1994; Polanyi, 1967). Explicit knowledge is formal knowledge that can be relatively easy to express, articulate, share, and transfer (Nonaka, 1994). Tacit knowledge is deeply rooted in an individual's actions and experience as well as in ideals, beliefs or emotions, which cannot be conveniently expressed or written down to communicate or share with others (Polanyi, 1967), as noted by Wood, et al. (2009, p.68) "you just feel it". Another type of knowledge related to tacit is procedural knowledge, which is a type of knowledge someone has and demonstrates through the procedure of doing something, i.e. knowledge gained from experience of undertaking a task. Procedural knowledge is situation- and context-specific (Goldkuhl and Braf, 2001) and contextualization is important to improve understanding of knowledge (Nonaka, 1994). As knowledge is created in various contexts, it cannot be perfectly understood when isolated from contexts (Goldkuhl and Braf, 2001). This requires information on who created the knowledge, and why, where, when and how it was created and used (Ahn, et al., 2005).

2.2. Lessons Learned

A lesson learned (LL) is a knowledge or understanding gained by either positive or negative experience (Weber, et al., 2001). Literature has been reported various formats and capture techniques for LL (Williams, 2008). A few common ones are LL sessions, after action reviews, project debriefings, post-project reviews and postmortems. Shortcomings of existing LL practices have been well documented across multiple industries (Tan, et al., 2006; Weber, et al., 2001; Williams, 2008), especially those related to Post-Project Reviews (PPR), the most common kind in many industries. Tan, et al. (2006) identified two major shortcomings with standard PPR practice. First, the learning captured is not shared effectively and there is no established way to locate the learning embedded in reports for reuse. Secondly, the current practice of distilling the key learning captured in PPR in point form is too brief for understanding and efficient sharing of the knowledge captured. Further, Goffin, et al. (2010) revealed that PPR reports are often limited to capturing merely explicit knowledge, and that much of the tacit knowledge that emerges in PPR is likely to be lost due to difficulties in articulating the way that tasks were performed and problems solved. Further, researchers have argued that the descriptions of the context and background of lessons are crucial for their reuse (Milton, 2010; Williams, 2008;). Milton (2010) reported that two factors determine the amount of context that is needed for lessons: their simplicity or complexity and the similarity of the context within which they will be reused. He stated that a simple lesson (i.e. a low-context lesson) can be documented in a few lines, expressed in a process flowsheet or diagram, and may be captured using a template. In contrast, a more complex lesson (i.e. a high-context lesson) may be highly situation-specific, are much more difficult to express in writing.

Tan, et al. (2006) proposed a methodology for LL, featuring background information, an abstract, conditions for reuse, relevant details and references. Similarly, Milton (2010) proposed a LL structure, including: context, description of the event, root cause of problems, lessons identified and suggested action. Several researchers assert that telling stories is an appropriate social method for capturing LL related to complex issues and skill-oriented tasks, especially those related to tacit knowledge (Goffin, et al., 2010; Milton, 2010). Stories are useful vehicles for capturing complex situations in a way that listeners can engage with and understand on a deep level (Goffin, et al, 2010). Orr (1996) found that Xerox's technicians employed storytelling for sharing problems, solutions and best practices from their day-to-day experience. *"Stories are good at presenting things sequentially (this happened, then that)...causally (this happened because of that). Thus stories are powerful ways to understand what happened (the sequence of events) and why (the causes and effects of those events)"* (Brown and Duguid, 2000, p.6). Milton (2010) acknowledged that a story can support a lesson by providing valuable background and context, and thus stories are easiest to learn from when they carry a learning point that is a specific, actionable recommendation.

2.3. Video Recordings

Video is an electronic medium for recording, copying and broadcasting moving visual images. The usefulness of video has long been recognized in several domains, such as education, health, design, e-learning and crafting. Video can convey much more of the detailed richness of a real setting than text, photos or audio recordings (Ylirisku and Buur, 2007). With their ability to scan the external environment and capture subtle, complex aspects of skill-oriented activities (as noted, *inter alia*, by Chua, et al., 2006; Wood, et al., 2009), videos enrich the description of knowledge with contextual cues. Ylirisku and Buur (2007) used video as a medium to raise designers' awareness of contexts in which products are used in more varied ways. They asserted that video captures what happens in the field with detailed richness—that is, portraying the personality and feelings of people—leaving more extensive room for discussion than text, photos and audio recordings. Furthermore, video has been identified as an efficient medium for conveying procedural knowledge and tacit knowledge, and invaluable for capturing subtle or complex aspects of performed activities (Wood, et al., 2009). Wood, et al. (2009) investigated the use of videos to elicit, record and transmit the tacit nature of complex skilled practices, such as crafting knives. They developed a web-based learning resource—with step-by-step instructions using video demonstrations—for novice craft practitioners based on observations and video recordings of an expert craftsman's working methods, tips and best practices. The study demonstrated that video-based learning resources offer more flexible learning modes for novice practitioners to acquire and refine difficult new crafting skills.

Many researchers have also shown that video recordings can enhance LL capturing practice. For instance, Sharif, et al. (2005) viewed videos as a medium that are capable of providing richer details related to lessons, are easy to understand and relate to new tasks, and thus their use improves chances for reusing lessons (Weber, et al., 2001). Similarly, Xerox technicians have proactively extended lesson representation with richer media attachments to further promote their reuse (Weber, et al., 2001). Further, the US Center for Army Lessons Learned (CALL) has used videos for recording field observations that are used to develop comprehensive training resources for various purposes, such as compilation of 'how to' videos on military operations (Weber, et al., 2001). Corbally (2005) found that scriptwriting was most important activity for producing purposeful videos. *"Never having written a script before, the estimation of time required to complete this was seriously underestimated. The development of the script can be likened to the blueprint of a building"* (p.377).

3. RESEARCH METHOD

Case studies have been employed as the overarching research strategy for this study, because it allows investigators to retain the holistic and meaningful characteristics of real-life events (Yin 2009). This paper is based upon qualitative data collected in three case studies in the aerospace industry. Interviewing is considered a primary means for collecting case study information, as it interpret participants' actions and openly describe problem situations. Data were collected through 56 semi-structured interviews, which were conducted during various sessions at the companies' facilities between May 2009 and August 2013. The average duration of the interviews was approximately 45-60 minutes. All the interviews were audio/video-recorded with the informants' approval. The knowledge lifecycle (KLC) stages (i.e. capture, store, share, search, access, and reuse) were used for all case studies to understand and analyse current organisational learning and knowledge management practices. Data were analysed using spreadsheets for drawing tentative conclusions, with a pattern-matching technique (Yin 2009).

Several themes were then drawn for further analysis based on patterns related to stages of the KLC. The themes were then analysed to understand the as-is LL practice, and to identify shortcomings of LL practice. A list of end-user's requirements and possible ways to address them were drawn in matrix format to develop an LL representation methodology. These activities were done iteratively in order to depict shortcomings, requirements and capabilities with the highest possible level of accuracy. Based on the enabling capabilities, a new methodology is developed for LL practice using videos (Chirumalla, 2013). Table 1 summarizes the details about three case studies.

Table 1. Overview of studies, methods used, and expected outcome.

	Study 1	Study 2	Study 3
Company	Process technology supplier	Aero-engine component manufacturer	Aero-engine component manufacturer
Duration	2009-2010	2009-2011	2012-2013
No.of respondents	11	25	20
Data collection methods	Interviews, focus groups, virtual meetings, workshop	Interviews, focus groups, survey, observations	Interviews, focus groups, observations, two pilot experiments
Outcome	Problem areas, needs, challenges	Detailed challenges and requirements	Enabling capabilities, solution, preliminary validation

In study 3 two pilot experiments were conducted with varying settings and setups: a laboratory experiment and an industrial experiment. The laboratory experiment was initially carried out with two researchers based at Luleå University of Technology to test the developed methodology for LL capture. One was working in the area of laser welding, while the other was working in the area of railway maintenance management. The methodology and detailed guidelines were introduced to the participants and they were each then asked to record a lesson they had learned, following the new methodology. The aim of the experiment, to test whether the methodology is helpful for capturing LL from skill-oriented activities, was fulfilled by producing two contextualized LL videos in a narrative form. The experiment also highlighted the improvement in adoption of the methodology as more experience is acquired in producing video-based LL. The next pilot experiment was conducted in the industrial environment of aero-engine component manufacturer. The methodology and guidelines were introduced to all industrial participants during the observational period. The *extreme or deviant sampling* technique (i.e. focusing on experiences with outstanding successes/notable failures; Patton, 2002, p.230) was used to identify information-rich participants to test and validate the proposed methodology. In total, the methodology was tested six times, with two design leaders and one quality engineer. After testing the methodology, the participants were asked to give their reactions and comments on the tested methodology using a follow-up questionnaire, which had five open-ended questions.

4. METHODOLOGY FOR LESSONS LEARNED PRACTICE USING VIDEOS

The case studies showed that the current procedures for capturing LL from manufacturing, serial production, use, and maintenance phases have varying ad hoc text-based formats, resulting in similarly diverse formats of lessons learned reports. In particular, they are not suitable for codifying lessons learned related to tacit dimension of knowledge from skill-oriented activities. The LL in skill-oriented downstream phases, which are crucial in early design phases for improving next-generation products, are even quite difficult to articulate and structure, as described by a production lead for manufacturing startup:

"I have a lot of experience in welding sheet metal parts, but it is very difficult to capture it...I know it and I have a feeling for it, but I can only capture some of it. The problem is that I cannot go into it deeply because I don't know how to express it exactly on paper ... so others cannot see where, how and why details and they will not understand what is important."

This highlights the problem of using a structural text-based format for codifying LL related to tacit dimensions of knowledge from skill-oriented activities such as sheet metal forming, in accordance with the findings of Wood et al. (2009) regarding knife crafting. These lessons from downstream phases are often highly contextual and, as concluded by Milton (2010), difficult to express in writing. Furthermore, from a reuse perspective, current practice lack contextual knowledge related to learning—that is, the lessons' background, analysis, root causes, and applicability—thereby demanding a method to capture LL at a process-based level with a richer context.

Based on several identified challenges and requirements like above, a methodology is developed for representing lessons learned in a standardized format, using videos as enabling media (Chirumalla, 2013). This methodology includes a seven-step representation format of lessons learned, consisting of: (1) lessons learned statement, (2) working context, (3) task description, (4) "what went wrong" or "what went well", (5) lessons learned, (6) lessons learned measures, and (7) applicability and delimitations. A set of guiding questions have been formulated for each step to help users to formulate their LL in a clear, concise, and informative manner, as shown in Table 2 (see Chirumalla (2013) for the rationale and detailed explanation of these seven steps):

1 - LL statement: This is a brief statement (short sentence) introducing the LL to knowledge seekers that summarizes the main points and explains why it is important.
2 - Working context: This provides information about the background and working situation of the task that the LL concerns, including the person's name, job role, project name, type of product, and operational level within the phases of the global product development process, and a list of stakeholders involved during the task.
3 - Task description: This is a short description of the task the LL concerns, including how it was executed, the conditions and circumstances where it was executed, and key parameters or tools that were used.
4 - What went wrong or what went well: This is a detailed explanation of successes or failures during the activity. It pinpoints where—and how—the problem/favorable outcome occurred as well as its effects on execution of the task or project.
5 - Lesson learned: This is a detailed description of the LL, recognizing the new or improved solution to avoid the problem or repeat the favorable outcome, including any additional relevant experiences. It focuses on what was learned that would benefit the performance of a future activity or project.
6 - Lesson learned measures: This describes how effective the LL was, for instance some measure of its effects on performance, such as a quantified change in time, costs or quality in the process relative to previous conditions.
7 - Applicability & delimitations: This spells out the applicability of the LL in terms of tasks and projects, including (for instance), potential beneficiaries (or target audiences), for whom it may be applicable, its limitations, and additional activities that may be required for further validation.

Table 2. Layout of the proposed lessons learned methodology format.

No	Steps	Guidelines	Notes
1	Lesson Learned Statement	Shortly summarize the main points about this lesson and why it is important for others to know.	
2	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?	
3	Task Description	*Briefly describe the task:* How was the task planned/executed? What key parameters or tools were used? What are the conditions when the task was executed?	
4	What Went Wrong or Well?	*Describe problems/successes that you came across during the activity:* What was the problem/favorable outcome? Where/How did you identify the problem(s)/favorable outcome? What is the effect of the problem(s)/success on task execution?	
5	Lessons 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?	
6	Lessons Learned Measures	*Describe the measures of the improved solution of the problem(s):* How can your LL improve the problem area or success area? How would you quantify the change/ improvement compare it with pre-existing solutions?	
7	Applicability and Delimitations	*Describe the applicability or limitations of the lesson learned:* Who are the potential beneficiaries of your lesson? Where can the lesson be applicable? What is the level of quality? What additional activities are necessary? What are the limitations of your lesson?	

5. PRELIMINARY VALIDATION RESULTS

The validation of proposed methodology is performed at two occasions with different set ups. This paper is presenting the results from the industrial experiment. The process for the validation is as follows: participants were asked to identify the lessons learned from their past experiences. Then they prepared and formulated the scriptwriting for the LL using the methodology (seven steps and guidelines). In a final step, they recorded the LL using a video and filled a questionnaire survey.

Three industrial practitioners (a quality leader, product support phase design leader, and a stress analysis leader) tested the LL methodology. A screenshot from the resulting LL video and a transcript is shown below in Figure 1 and Table 3, respectively. This captured LL is from the serial production and product support phase. The design leader prepared and explained a lesson-learned story regarding inspection criteria, following the methodology's steps and guidelines, as shown in Table 2.

Fig. 1. Screenshot from the serial production inspection criteria lesson learned video.

This LL from the product support phase is procedural and context-specific knowledge, which needs to be shown and explained in a visual manner, as shown in Figure 1. In the experiment, the practitioner pointed out the relevant location on the product four times, as shown in Table 3, to show the circumstances in which the problem and lesson identification occurred (as in the earlier laboratory experiment). Thus, video-based LL can captures what happens in the field with detailed richness, as claimed by several authors, such as Wood, et al. (2009) and Ylirisku and Buur (2007).

Table 3. Captured LL about inspection criteria in a serial production (transcribed from LL video).

Lessons learned statement
During large-scale serial production of cast parts, it would be much too costly to check all the dimensions specified in the drawings. Therefore, generally a plan for reduced inspection is formulated in association with the first article inspection review (FAIR). This lesson learned is basically about the criteria that must be met to accept the reduced inspection plan.

Working context
My name is Stefan Jansson. I have been working at (…) for the last five years. Currently, I work as a design leader in the Trent 900 Intermediate Compressor Case (ICC) product support team. This ICC is part of (….)'s Trent 900 engine, which is mounted on the (…..) airplane (pointing to it in the video). The stakeholders related to this task will be design and quality control personnel at the company or the casting supplier, which in this case is the American company (….).

Task description
During visual inspection upon parts arrival, it was suspected that the front engine mount package (pointing to it in the video) tilted somewhat. In order to check this, we decided to thoroughly measure this front engine mount lug. During this thorough measurement it was concluded that the front engine

mount was tilted, but also these regions (pointing to them in the video), which we call bridges, between the lugs were a bit too thin, thinner than specified in the drawing.

What went wrong?
The problem was that the casting supplier changed the casting process after the first article inspection review. During the first article inspection review, this dimension here between the lugs (pointing to the location in the video) was excluded from the inspection plan. However, what they should have done was that as soon as they changed the casting process the reduced inspection plan should have been updated to make sure that any excluded dimensions were still fulfilling the drawing requirements. The problem with this deficit in the mean thickness of the bridge region is that the component's life fatigue was not fulfilling requirements anymore (pointing it in the video). This came to our knowledge after we went through the first article inspection review documents and discussion with the clients.

Lesson learned
One of the root causes of this problem was that the initially accepted reduced inspection plan was never updated after the casting process changed. In order to find this root cause, we performed "5 times why" analysis, both here at the company and together with the casting supplier. In addition, we performed what we call a Kepner-Tregoe exercise, which is also an analytical procedure to find the root cause of problems such as this. To avoid this problem occurring in the future, our quality department will send out a requirement document clearly stating that after changing any casting process after an initial FAIR, a delta FAIR needs to be done to ensure that all the part's dimensions still meet requirements.

Lesson learned measures
I believe that this lesson learned will have a significant impact on both our product's technical requirement fulfillment and costs, because if we can identify and resolve such problems, we won't need to do repair work and obviously the product cost will be lower. In addition, we won't have to handle non-conformances that we would usually discover later in the process.

Applicability & delimitations
I believe that this lesson learned is relevant for all the company's cast products. It should be vital to everyone working within design, quality and production.

6. EMPIRICAL RESULTS AND DISCUSSION

From the questionnaire responses it was observed that two out of three of the practitioners (the quality leader and design leader) found that the methodology with well-defined steps and guidelines was helpful for structuring a LL in a meaningful way. One of the practitioners said that:

"I think that the template is a good help to define the lessons learned generation process. If prepared, I think this is a good way to spread information from experience."

This means the practitioners found that the methodology is good enough to guide them to generate LL from downstream phases, such as manufacturing and product support phases, with more details. As they lacked a generic level format to capture process-based LL from downstream phases, they believed that the proposed methodology is a better choice to leverage these high-context specific lessons than current alternatives. The third respondent (the stress analysis leader) found it difficult to summarize the simulation and stress analysis results in a narrative form, despite being enthusiastic about trying new methodology. The main reason was that this LL has many technical parameters and technical graphs, making it difficult to explain in a narrative form. In current practice he often shares this lesson with others in a Powerpoint presentation. However, he said that more practice would help him to structure a decent story that would be useful to others in the organization.

The practitioners were asked how easy they found the method to use compared to the text-based LL approach. All of them agreed that experience-based "knowing" is easier to record with video-based LL compared to the text-based approaches. This is described by one of the practitioners as follows:

"Using videos for lessons learned can be beneficial as it allows us to capture and highlight good or bad examples from production such as design mistakes found in the manufacturing phase… That cannot be easily documented to understand them. You have to see them. I mean it is easier to see someone explaining how a fixture works than to read about how to fix it."

This shows that video-based LL opens up new possibilities for people involved in manufacturing and later downstream phases to provide a rich overview of processes, especially for highlighting specific features of product components. According to the practitioners, these videos could allow them to provide recommendations to designers at a specific component level. For instance, if the designers are working on a cast product, using video LL they can be shown visually that "*You should think about these problems in the design phase*". In this way, video-based LL can convey a learning point with more specific details and actionable recommendation to the component designers in early phases, enabling them to access more context-specific lessons than traditional project-specific LL documents. In addition, all practitioners agreed that it is easier to capture people's interest by a video than by a written document, as concluded by several previous authors, e.g. Daily (1994) and Ylirisku and Buur (2007).

However, the practitioners also agreed that behavioral changes are required to adopt the new methodology. They emphasized that motivating people to appear in videos and explain their LL would be a major challenge, but also said that this does not apply only to videos, but also to implementation of any new procedure within the company. Implementation of training programs and aligning the capturing process with routine business activities are considered to be crucial. To improve adoption of the new methodology it will be important to provide users with detailed guidelines for preparing, producing, editing and publishing well-structured videos. One practitioner noted the importance of training as follows:

"I looked at it [the methodology] for the first time just 5 minutes before we started making the video, and if I had looked at it more closely, I could have understood it better and produced a better lessons learned video."

This response echoes similar opinions expressed by practitioners in the earlier laboratory experiments, that more practice would help them to produce better videos, and was corroborated by recordings of the time taken to capture an LL by the participants. It was found that the time taken (including all the steps they took while recording the video) substantially declined with increases in the number of trials, for instance for industrial participant 1, from 25 minutes in trial 1 to 10 minutes in trial 3. This shows that practitioners can produce LL videos more quickly after acquiring experience.

The case company of studies 2 and 3 currently changes process flows in its design practice system based on LL reports that lack the rationale for reported modifications. In such contexts, LL videos have been found to be useful as rationale carriers to explain to novice designers *why processes are as they are* and *why products are the way they are*. Thematically classified LL captured by video could provide a valuable knowledge base for tutorial-based training for novice designers as well as for development teams before they begin new design projects, as also noted by Chua, et al. (2006) and Wood, et al. (2009). All of the practitioners believed that such a video-based solution would be useful for fostering a cross-project learning environment within the company by disseminating LL from successful and unsuccessful outcomes, for instance good and bad examples from production and inspection. This could leverage problem-based learning that enhances novice workers' deep learning on various complex issues. In accordance with earlier researcher claims regarding the information a person can absorb when watching videos rather reading a lot of text, one of the senior design leaders said that:

"You know the saying that a picture is worth 1000 words. Then imagine the flow of pictures in a video. You are seeing things happening, and then you really understand what is going on, what is it, how it works and so on."

This implies that using videos for capturing LL can provide more background and contextual understanding of complex issues, thereby stimulating learning and reuse in new situations, as identified by Chua, et al. (2006).

7. CONCLUSIONS AND FUTURE WORK

With the unprecedented speed at which customer needs are changing, the speed at which companies learn from past experiences and ongoing initiatives is becoming critical to bring forward innovative product solutions. In order to cope with new challenges in the setting of complex product development, enhanced methods and tools are needed to improve the capture and reuse of LL from different phases of products' lifecycle to support early design phases. In this line, the author proposed new methodology for LL practice, includes a standard, seven-steps representation format together with guidelines, using videos as enabling media. Preliminary validation showed that the methodology could help industrial practitioners by lowering the threshold for capturing experiential knowledge from manufacturing and product support phases with richer context. In particular, the methodology could facilitate the preparation and formulation of concise LL with richer context than traditional text-based formats. The methodology seem to be beneficial in capturing lessons from skill-oriented activities in a narrative form, by visually displaying defects, problems or improvements in complex products and associated actions in production or maintenance phases, for instance. These videos seem to be useful as rationale carriers and good training materials for novice engineers because they capture a single learning point at a process-specific level, including specific details and actionable recommendations to support the early design phases.

Further research is needed to thoroughly evaluate the methodology in terms of the time required to (1) formulate, (2) record, and (3) edit and publish a LL, compared to the text- based approach. During the experiments, YouTube® was used as a video repository, in which basic tagging, bookmarking, and annotation functionalities were tested, but not with participants. In future research a full-scale video-based LL capturing portal should be developed, permitting participants to access LL capturing videos, store and share them with tags and bookmarks, thereby allowing other people to search for and access relevant video-based lessons for reusing in a new design task. Future work should also address the effect of "pushing" relevant LL to the users (via alert notifications) relative to "pulling", i.e. users searching for them within the system.

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