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1. Introduction

1 Knowledge is part of the intellectual, historical, and cultural capital of industry. The Organization for Economic Cooperation and Development (OECD) reports that :

> "knowledge is now recognised as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance. […] The need for workers to acquire a range of skills and to continuously adapt these skills underlies the "learning economy". The importance of knowledge and technology diffusion requires better understanding of knowledge networks and "national innovation systems". […] Identifying "best practices" for the knowledge-based economy is a focal point of OECD work in the field of science, technology and industry" (OECD, 1996, p. 3).

2 In the industrial world, the transmission of expert knowledge (Arrow, 1969 ; Newell & Simon, 1972) has become one of the major challenges facing society, especially in the current context of the mass retirement of a generation of highly skilled, expert workers. The large industrial companies that emerged in Europe from 1950 to 1970 hired massively during that period. This led to the development of a body of specialized knowledge and know-how developed by an entire generation of company experts. They took part in the creation of the first large industrial projects (e.g., power plants), the first orbiting satellites, the first supersonic aircrafts, and the first high-speed trains. The continuing existence of this knowledge capital is now however being threatened. Indeed, it is likely to disappear as senior qualified workers retire if nothing is done to address this challenge. For the work world, the consequences of such a loss would be disastrous not only from an economic and strategic viewpoint (the production and durability of companies is at stake), but also for the mitigation and preservation of workers' health and safety, since the transfer of experiential knowledge is at the base of occupational risk management. The demographic transition issue resulting from the retirement of the baby-boomer generation entails an urgent need to "capture" and "transfer" the professional know-how developed by these experts so that it is passed on to the next generation of workers. Mentoring in skilled trades (Argyris & Schon, 1974 ; Castéra, 2008 ; Cushion & al., 2003 ; Furlong & Maynard, 1995 ; Schön, 1983 ; Zanting & al., 2003) as a socialisation practice (Nonaka & Takeuchi, 1995) is an option frequently used in manual sectors to enable on-the-job, face-to-face cognitive, social, and experiential sharing between experts and novices. Unfortunately, this kind of training is becoming less possible as time pressure increases and experienced, highly qualified workers retire en masse. Companies are now increasingly trying to up-date their training systems with video media. Given the current situation, concerned communities and industries want to find new, digital-based solutions to preserve and transfer the know-how developed and accumulated by highly qualified workers.

3 The problem of accessing the immaterial, subjective wealth that is knowledge can be clearly seen in the epistemological distinction between tacit and explicit knowledge (Nonaka & Takeuchi, 1995 ; Polanyi, 1958, 1967 ; Ryle, 1945). Explicit professional knowledge is often formalised through procedures, schematic representations, and industrial documents. Nonetheless, while these types of prescriptive documents are necessary, they are not sufficient for training novices. Tacit knowledge is linked to experience ; it is personal, context-specific, and therefore hard to formalise and communicate (Nonaka & Takeuchi, 1995). Operators are unable to express all their goals and intentions because of the limited vocabulary of languages

to articulate these ideas. In short, the collection and formalisation of specialized know-how for transmission purposes are the main methodological issues of knowledge management.

4 Different methods in knowledge management (Cloutier & al., 2012 ; Earl, 2001 ; Ermine & Boughzala, 2006 ; Lamari, 2010 ; Nonaka & Takeuchi, 1995 ; Srikantaiah & Koenig, 2000) have come to the fore over the past twenty years ; the use of video as a media to convey expert knowledge (Arrow, 1969 ; Newell & Simon, 1972) for occupational training purposes in operational and manual activities, though promising, still remains a challenge. Occupational training and the technological means (mainly, simulation) to achieve it are being developed at the crossroads between ergonomics and educational sciences (Aubert, 2000 ; Boccara & Delgoulet, 2013 ; Caes-Martin, 2005 ; Chassaing, 2004 ; Fauquet-Alekhine & Pehuet, 2011 ; P Pastré, 2005 ; Samurçay, 2005 ; Vidal-Gomel, 2007). The scientific literature also notes that the professional fields that make the most use of video media for training are primarily teacher training (Goldman, 2007 ; Mottet, 1997 ; Sawyer, 2006 ; Vonderen & al., 2010 ; Weiss & al., 2006) and emergency care units (Alison & Crego, 2008 ; Crego & Harris, 2002 ; Eary, 2008 ; Hamilton & al., 2002 ; Jowett & al., 2007 ; Mondada, 2003, 2004 ; Palter & al., 2010 ; Powell & al., 2008)

5 In the manual sector, some homemade videos are produced by trainers or field operators in industry to meet their needs for innovative teaching tools. That being said, they generally use a prescriptive approach that shows what must be done according to the rules. However, novices also need to feel their way around and "to experience" the movements in order to be able to grasp and share the expert's cognition :

> "without some form of shared experience, it is extremely difficult for one person to project her- or himself into another individual's thinking process" (Nonaka & Takeuchi, 1995, p. 63).

6 How can we standardise occupational know-how well enough to transmit it through video media ? This paper presents a real-world study (Gray, 2013 ; Robson, 1993) that uses embodied (Anderson, 2003 ; Barsalou, 2010 ; Varela & al., 1991), situated (Suchman, 1987), and distributed (Hutchins, 1995b ; Norman, 1988) cognition models to make expert, tacit knowledge explicit. To achieve this aim and overcome the limits of knowledge transmission, we designed a method that combines : (1) tools of visual ethnography, particularly the first-person perspective digital ethnography (Goldman & al., 2007 ; Knoblauch & al., 2006 ; S. Lahlou, 2011 ; Omodei & al., 2005 ; Pea, 1994 ; Rix-Lièvre & Lièvre, 2010) provided by a subcam (subjective camera) (Lahlou, 1998) which is a small digital camera worn at eye-level by the expert himself ; (2) theoretical and methodological frameworks drawn from ergonomics and work psychology, especially Activity Theory (Daniellou & Rabardel, 2005 ; Leontiev, 1978 ; Nosulenko & Rabardel, 2007 ; Nosulenko & Samoylenko, 1997) and Perceived Quality Approach (Nosulenko & Samoylenko, 2009) ; and (3) verbalisation methods (Bisseret, 1981 ; Brommel, 1983 ; Clot & al., 2001 ; Clot & Kostulski, 2011 ; Ericsson & Simon, 1980 ; Falzon, 1991 ; Flaherty, 1974 ; Leplat & Hoc, 1981 ; Mollo & Falzon, 2004 ; Theureau, 2003 ; Titchener, 1912) in order to analyse occupational expertise embodied in human activity.

7 This method, called ECAST, led to the development of a new kind of educational training media, called Multimedia platform for APprenticeship (MAP). It is intended, through its content and structure, to enable novices to put themselves in the shoes of an expert and to adopt the expert's perspective by using all the collected material such as video observations and verbalisations, a technique whereby workers comment on their work. A qualitative evaluation comparing traditional systems with the new MAP-based training system was conducted. An overview of the main collected observations is presented here.

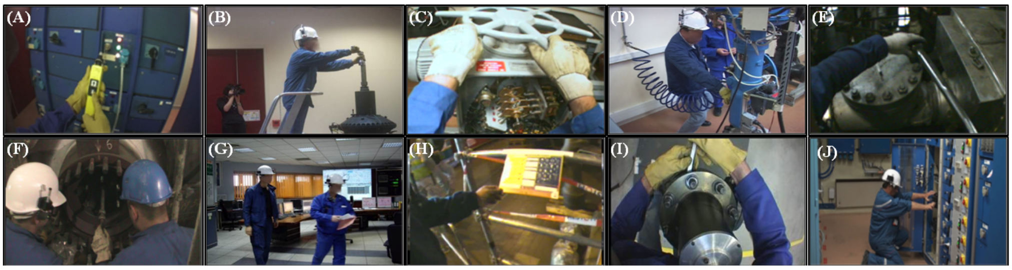
2. Materials and methods

2.1 Materials

8 This study was undertaken in conjunction with the Research & Development Department of France's largest electricity supplier for its Training Department. It primarily concentrated on know-how embodied in a specific class of human activity, namely professional gestures. We define a professional gesture as a delimited, perceptual-motor segment of work activity

comprising expert skills and guided by motivations and goals (Le Bellu & Le Blanc, 2012). Professional gestures targeted by the company belong to a category of experienced, skilled work movements identified as being "rare" or "critical" since they require quite specific know-how. Professional gestures labelled as rare are those which rely on unique skills that only a handful of operators have or those which are conducted on rare occasions. Critical gestures are those that involve working on sensitive activities. They potentially involve a high-risk impact both on the operators' health and safety and on organisational production (risks of failures, material damage, production delays, etc.), with the latter often leading to the former. These critical gestures can be performed during unit shutdowns or while building or dismantling a site.

Figure 1. Sample of the corpus of professional gestures studied here



Capture screens from : (A) PG1 : Remotely operating a tap. (B) PG2 : Manually setting a tap. (C) PG3 : Diagnosing a dysfunctional electronic valve. (D) PG4 : Diagnosing valve failure. (E) PG5 : Controlling valve tightness. (F) PG6 : Closing a condenser. (G) PG7 : Consigning a pump. (H) PG8 : Completing safety operator rounds. (I) PG9 : Tightening a bolted assembly. (J) PG10 : Inverting a charger.

9 Fifteen gesture situations were considered for our corpus of empirical data. Ten of them were work situations within the company context (figure 1), and the remaining five were gestures performed outside of the company, in different contexts (while playing sports, driving, conducting car maintenance, etc.) in order to compare and test the robustness and reliability of the method we designed.

10 Among the ten professional gestures, five of them (PG5, PG6, PG7, PG8, PG10) were performed by operators working in power plants whereas the other five (PG1, PG2, PG3, PG4, PG9) were completed in the company's main training centre by operators-turned-trainers, on full-scale models of plant machines and installations.

11 These professional gestures were selected to meet research objectives after consultation with the project staff members, the project's operational contacts (who were specialists in both the field and training contexts), as well as trainers for gestures filmed in the training environment and power plant staff (managers and operators) for gestures filmed directly in the plants during real work activities.

12 Nineteen subjects participated in these field experiments in at least one of the three following steps : (1) the initial semi-structured interview for preparing the capture of the professional gesture (lasting 20-90 minutes and using a topic guide) ; (2) the data collection phase ; and (3) the final individual and group self-analysis interview (lasting 44-145 minutes, the media guides used in the self-analysis interview are described in the section "Methods"). Field notes were made by the researcher during and after the interviews, and sometimes a colleague of the participant and/or of the researcher was present during these steps.

13 All of the participants were highly skilled operators recognised for their expertise by the organisation (managers and peers).

Table 1. Case studies collected during the first exploratory phase

Case	Professional gesture	Location	Participant	Camera	Verbalisation
1	PG1	TC	S2	Glasses	NV
2	PG1	TC	S2	Helmet	STAV
3	PG1	TC	S2	Helmet	GOTAV
4	PG1	TC	S2	HD-bandana	GOTAV
5	PG2	TC	S2	Helmet	NV

6	PG2	TC	S2	Helmet	STAV
7	PG2	TC	S2	Helmet	GOTAV
8	PG2	TC	S2	HD-bandana	GOTAV
9	PG2	TC	S3	Helmet	GOTAV
10	PG3	TC	S1	HD-bandana	STAV
11	PG3	TC	S2	Helmet	STAV
12	PG3	TC	S2	HD-bandana	GOTAV
13	PG4	TC	S1/S2	Helmet	SVCOM

HD = High Definition ; TC = Training Centre ; NV = No Verbalisation ; STAV = Spontaneous Talking Aloud Verbalisation protocol ; GOTAV = Goal Oriented Talking Aloud Verbalisation protocol ; SVCOM = simulation of a mentoring situation, namely an expert who explains to a novice how to do a movement

Table 2. Case studies collected during the second and third phases

Case	Professional gesture	Location	Interview Preparation	Capture step		Individual and group self-analysis interview
				Participant	Verbalisation	
14	PG5	PP	--	S4	STAV	S4
15	PG6	PP	--	S5, S6	NV	S9
16	PG6	PP	--	S7, S8	NV	S9
17	PG7	PP	S10, S11	S12, S13	NV	S10
18	PG8	PP	S14, S15	S14	NV	S14
19	PG9	TC	S16/S17	S16 (S17)	NV	S17
20	PG9	TC	S16/S17	S16 (S17)	GOTAV	S17
21	PG10	PP	S18	S18	NV	S18/S19
22	PG10	PP	S18	S18	GOV	S18/S19
23	PG10	PP	S19	S19	NV	S18/S19
24	PG10	PP	S19	S19	GOTAV	S18/S19

PP = Power Plant

14 In total, twenty-four case studies were collected and analysed (Table 1 and 2).

15 The qualitative variables were the following : the type of subcam (we tested several devices), the verbalisation protocol, the number of operators involved in the execution of the professional gesture, the location of the work situation, and the work situation (the kind of gesture). This collected material comprised approximately fifty hours of audio and video recordings. Several technical documents were also collected for each of these professional gestures (procedures, schemes, etc.). The expert(s) involved in the data collection phase was/were equipped with the subcam, whereas the researcher filmed the setting with an external camera (the audio-video recording technique is described in greater detail since it is an integral part of this study).

16 Four phases of data collection were executed in keeping with the "experimental reality" paradigm (Lahlou, 2010). This means that the method (presented in the results section) was created, tested, and refined in real situations with and for trainers, in an iterative manner, by gradually increasing the complexity of the capture method.

17 The first collection and analysis phase (cases 1 to 13, see Table 1) was exploratory and took place in a re-created setting of the plant, namely the main training centre. It enabled the testing of various elements, namely the types of observation and subjective video-recording devices, the verbalisation protocols, and the types of professional gestures. This first phase led to the development of the initial version of the gesture capture method and a model for characterising gestures which revealed their complexity (Le Bellu & Le Blanc, 2012).

18 The second collection and analysis phase (cases 14 to 18, see Table 2) tested the method's feasibility in real work situations in power plants, and its applicability to more complex professional gestures. Observations and findings from this phase led to protocol modifications and emphasised parameters that might be altered by the nature of the data capture situation (real or re-created).

19 The third collection and analysis phase (cases 19 to 23, see Table 2) tested the robustness and reproducibility of the method both in real and re-created settings.

20 The protocols, methods, and techniques that were part of the knowledge management method we conceived were gradually refined during the design phases, involving increasingly complex professional gestures and settings. They are detailed in the section "Methods and theoretical background."

21 Finally, a fourth and final phase dedicated to a qualitative assessment of the MAP-based training system was completed by observing and comparing three real pilot training sessions (two with the MAP, one without) in the company. These training sessions took place in the company's main training centre, in keeping with the conceptual framework of an off-the-job / structured / active workplace learning situation (Jacobs & Park, 2009).

22 A light assessment protocol was designed by taking into account the number, time and availability constraints of trainers and training sessions (related to industrial contexts). It aimed to answer the following question : "What can MAP-based training be ?" The protocol likewise attempted to collect the actors' (trainers and trainees) feelings and perceptions about the use and the usability of the MAP in training conditions in order to gain a qualitative appreciation of the acceptability of this new tool as compared to traditional training methods.

23 All three training courses lasted two days and focused on tightening a bolted assembly (professional gesture PG9 on figure 1 - Picture I).

24 A traditional course without the MAP and two courses (a pilot and an experimental) based on the MAP modelling of professional gesture "PG9 : Tightening a bolted assembly" (see figure 1, Picture I) were analysed and compared on the basis of qualitative data. It was agreed that including the MAP in the training process must by no means disturb the traditional instructor-apprentice course in the training session. We gave the trainers the freedom to use the MAP as they liked.

25 These three sessions were led by the same two instructors who both belonged to the occupational training staff of the company's training centre : one of the two instructors was a former operator having spent most of his career in the company and had extensive field experience ; the second was a younger instructor who was directly recruited to teach because of his strong theoretical background. All of the company's professional instructors were taught appropriate educational techniques (mentoring, group work, etc.) upon their arrival in the company.

26 Approximately ten apprentices attended each course.

Table 3 : Assessment protocol of how the MAP was employed in real occupational training sessions

Session	Trainers / Apprentices	Protocol	Material
Pilot	F1, F2 / 10 apprentices	Session with MAP	/
Traditional	F1, F2 / 10 apprentices	Session without MAP	Audio-video recording of the two-day session, I1, FG1
Experimental	F1, F2 / 9 apprentices	Session with MAP	Audio-video recording of the two-day session, I2a, I2b, FG2, S

IHDy trainerses of use, suggestions of improvement, etc. nd drawbacks of g of the focus group, could use it. Watch the videos at = Semi-structured Interview ; FG = Focus Group ; S = Survey

27 The pilot session (Table 3) was intended to allow the trainers to test, for the first time, the integration of the MAP device in their course. No data collection was conducted.

28 The traditional training session (table 3) was conducted by the trainers based on regular conditions and ways of carrying out the training, that is to say, without the MAP. This session was observed and audio-video recorded. Two verbalisation protocols were likewise conducted, namely : (1) a semi-structured interview with both trainers (I1) in order to collect their observations and feelings based on a comparison of the previous pilot session and the traditional one (difficulties met, advantages, disadvantages, behaviour of the group, work performance observed and felt) ; and (2) one focus group (FG1) with the 10 apprentices in which two researchers presented the MAP and had the apprentices watch the videos at the end

of the two-day training in order to gather their advice and perceptions regarding the usefulness of such a resource.

29 The educational objectives in the experimental training session (table 3) included the MAP, its integration being decided by the two trainers. The results of the MAP's integration in the training are presented in section 3.3. This session was also observed and audio-video recorded. Three verbalisation protocols (VPs) were conducted. This included two semi-structured interviews (VPs 1 & 2) with both trainers who collected observations and feelings based on a comparison of the previous sessions and this one (difficulties met, similarities, differences, advantages, disadvantages, work and learning performances noted by apprentices). The other protocol (3) worked with a focus group with 9 apprentices. It employed a survey specifically designed to be completed at the beginning of the focus group in order to collect and guide the discussion themes (e.g., general feedback on the MAP, feedback on the different ways it was used during the two-day training, assessment of the main steps of the professional gestures, good practice and points to be careful about, perception of advantages and drawbacks of such a use, difficulties of use, suggestions for improvement).

30 Qualitative data obtained through observations, interviews, surveys, and focus groups enabled us to collect the trainers' and apprentices' thoughts about the quality of the training and learning process when using the MAP in the course.

2.2 Methods and theoretical background

31 This section presents the theoretical and methodological frameworks used to address the issue of accessing and analysing tacit and explicit know-how embodied in professional gestures. We used an approach which is based on the Russian stream of Activity Theory (Leontiev, 1978 ; Nosulenko & Rabardel, 2007 ; Rubinstein, 1922 ; Savoyant, 2005), the Perceived Quality Approach (Nosulenko & Samoylenko, 2001, 2009), the subjective evidence-based ethnographic paradigm (Lahlou, 2011), and verbalisation techniques (Bisseret, 1981 ; Brommel, 1983 ; Clot & al., 2001 ; Clot & Kostulski, 2011 ; Ericsson & Simon, 1980 ; Falzon, 1991 ; Flaherty, 1974 ; Leplat & Hoc, 1981 ; Mollo & Falzon, 2004 ; Theureau, 2003 ; Titchener, 1912). These four approaches form the core of the methodology, which aims to highlight various elements of an expert's knowledge of a professional gesture that are considered to be important for transmission purposes. The originality of this study lies in the fact that the methods and theoretical background presented in this section were utilised both to study the activity and to compose the final method, since one of our concerns was to design a method of knowledge management which could be transmitted to other practitioners.

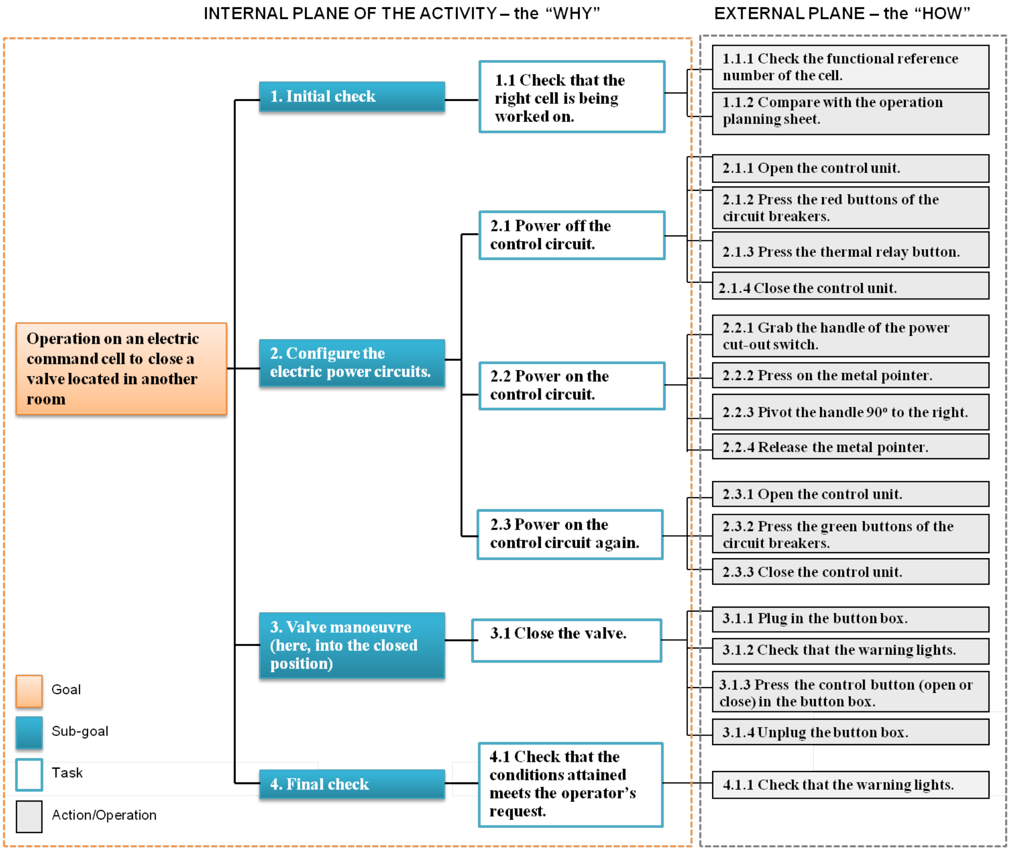
32 Furthermore, we took into account developments in cognitive science, especially those concerning the distributed (Hollan & al., 2002 ; Hutchins, 1995a, 1995b ; Rogers & Ellis, 1994) and situated (Lave, 1988 ; Suchman, 1987) dimensions of human actions and cognition.

2.2.1 Activity Theory

33 Activity Theory enables real human activity to be analysed and structured. Activity can be defined by a range of properties (Barabanschikov, 2007) : it is conscious and initiated by an individual (it does not exist in itself) ; it is an objective to reach ; it is social and therefore falls within a communication system ; and it requires resources (tools) in order to transform the world, which in turn guides actions. Occupational activities have these properties and activity theories can analyse them in technological contexts. These theories, which first appeared in the USSR in the early twentieth century (Leontiev, 1978 ; Rubinstein, 1922, 1940), brought a new perspective to human activities by detailing how an environment can be psychologically adapted to men working in complex technical systems. These theories are one of the key foundations of the development of the fields of psychology and ergonomics. Many versions of activity theory were and still are being developed and modified (Bedny & Karwowski, 2004 ; Bedny & Meister, 1997 ; Bödker, 1996 ; Daniellou, 2005 ; Decortis & al., 2000 ; Engeström, 2000 ; Nardi, 1996 ; Nosulenko & al., 2005 ; Nosulenko & Rabardel, 2007 ; Von Cranach, 1982 ; Wertsch, 1998). While theoretical work on Activity Theory is relatively sophisticated, publications focusing on methodological approaches that would actually allow it to be applied to the study of work activity have lagged behind. This study leverages the

psychological structure of the activity developed by the Russian stream of Activity Theory (Leontiev, 1978 ; Rubinstein, 1922, 1940) but does not use its philosophical aspects linked to personality, conscience, motivations, and emotions.

Figure 2. The goal tree model



An example of how our adaptation of the Activity Theory model was applied to a professional gesture PG1. Remotely operating a tap (figure 1A).

34 Our adaptation of Activity Theory gives the following model : as Activity Theory describes the subject's point of view, it naturally links the "objective" and the "subjective".

35 Drawing our example from figure 2, activity can be considered as two parallel planes, namely : (1) an internal, subjective, invisible plane which is related to the goals, sub-goals, and tasks ; and (2) an external, objective, and visible one that is composed of structural units, that is actions and operations. Applied to the problem of capturing occupational know-how, the theory allows a simultaneous analysis of the subjects' behavioural data obtained from external, so-called "objective" observations, and of their subjective experience through data provided by the subject himself (i.e., what (s)he "thinks" and says). To some extent, this structure respectively represents the "how" and the "why" of the activity. We can then more precisely define the activity's structure by carrying out an analysis of its distinctive components and of their organisation to form a "goal tree" model (figure 2).

36 The activity is carried out through actions subordinated to conscious goals. More precisely, *goals* are the essential component of the activity's structure. They form the activity, determining its features and dynamics (Leontiev, 1978). The activity's expected result, embodied in the principal goal, guides the accomplishment of actions. This principal goal, which "pulls" the activity along, is a representation of the outcome that the subject wishes to achieve. The course of action is determined by completing a sequence of *tasks* which are considered as goals specific to given conditions. These tasks are implemented by means of *actions* or *operations* (routine actions which are no longer conscious). Actions/operations are the basic level of behaviour (e.g., to take a cup, to push a button, to pick up the phone).

37 These components of the activity are not static. They form a system in which relationships between elements can shift : when an action is no longer conscious, it becomes an operation,

and this operation can become an action again if a problem appears suddenly and interrupts the automatic process of execution. This dynamic process enables the model to adapt to changes in a situation, and thereby respond to the constantly changing flow of human life.

38 Activity Theory thus provides a convenient framework for decomposing, structuring, and analysing human activity. This approach seeks to link and explain behaviours in light of the operators' goals and contextual conditions. Indeed, context often presents constraints and affects how the subject will act to achieve her/his goals. This justifies the need to run qualitative studies in the real world. Moreover, Activity Theory emphasises the functional values of the environment from the subject's point of view, namely the way (s)he uses a particular object or tool to achieve her/his goals. As a result, the environment gives meaning to the subject within the scope of a given activity : an object can be an aid or an obstacle, giving the object its "perceived quality" (N.B., this concept is defined in the next section).

2.2.2 "Perceived Quality" Approach

39 The "Perceived Quality" Approach (Nosulenko & Samoylenko, 2009) combines elements from Activity Theory (Leontiev, 1978 ; Rubinstein, 1922) and mental image theory (Lomov, 1982, 1984 ; Ohanin, 1973 ; Welford, 1961). In particular, it employs elements used to study and analyse daily life and work activities and their relation to objects that the subject considers to be relevant when (s)he determines her/his intentions. In this context, "perceived quality" can be defined as

> "a set of subjectively relevant features of the world and an activity that is formed by the subject in order to achieve her/his goals" (Nosulenko, 2008).

40 This approach provides a psychological perspective that seeks to understand what is perceived by the operator while performing an activity such as a professional gesture. In a real situation involving such a gesture, the number of external parameters that can be observed is almost infinite. It is therefore not possible to define *a priori* the number of so-called "objective" components to observe and "measure." In the Perceived Quality Approach, we are only interested in those components that are relevant for the expert, that is to say, the characteristics that make up the perceived quality of the gesture.

41 These subjective components can be identified and interpreted with scientific methods that ensure the objectivity of the research, especially by analysing the operator's verbalisations (Nosulenko & Samoylenko, 2009). The purpose is to match these components of perceived quality – in this case, oral explanations given by the operator who executes a professional gesture – with observations ; in the present study, it is first and third person perspective video recordings of the gesture accomplished in a technical context (see the next section "Video ethnography").

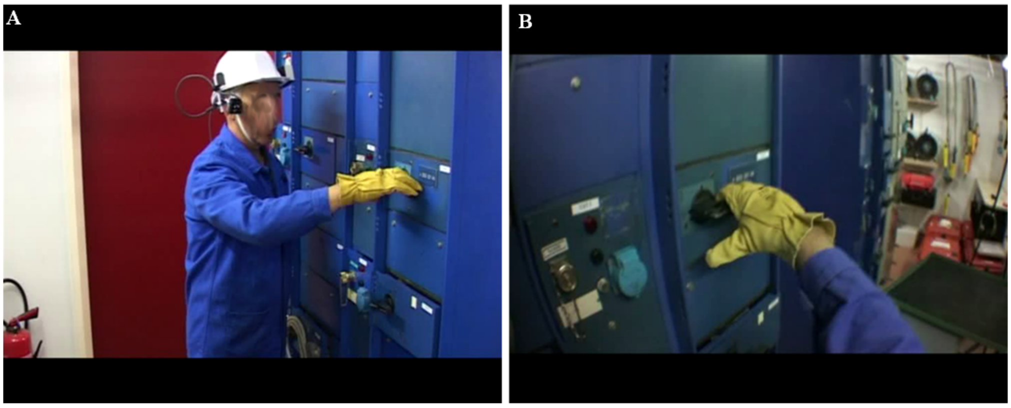
42 In summary, this approach provides a framework that enables the mapping of objective data (video recordings, results of needs analysis, analysis of procedures and documents, etc.) with subjective data characterising the personal experience of the operator (verbalisations about objects and components of perceived activity). In addition to helping us understand a professional gesture, the Perceived Quality Approach can help to improve the quality and design of the activity. By encouraging self-reflection on work practises, it can help operators to perform gestures better (easier, safer, more efficient, etc.).

2.2.3 Video ethnography : first and third person perspectives

43 Video ethnography is a naturalistic approach, enabling the capture of activity flow during real practices. Over the past ten years, there has been an increase in visual ethnographic methods and techniques. They have been used by social scientists in various disciplines (sociology, anthropology, psychology, ergonomics) in order to observe and study human and even animal activity in a qualitative way (Goldman & al., 2007 ; Heath & Hindmarsh, 2010 ; Lahlou, 2011 ; Mondada, 2006 ; Muséum de Toulouse, 2014 ; Pink, 2007).

44 To obtain the visible and external data of an activity, we used a double system of video data recordings : a first more conventional flow capturing a third-person perspective and a second flow providing a first-person perspective of the subject's activity (figure 3).

Figure 3. Third versus first-person perspective

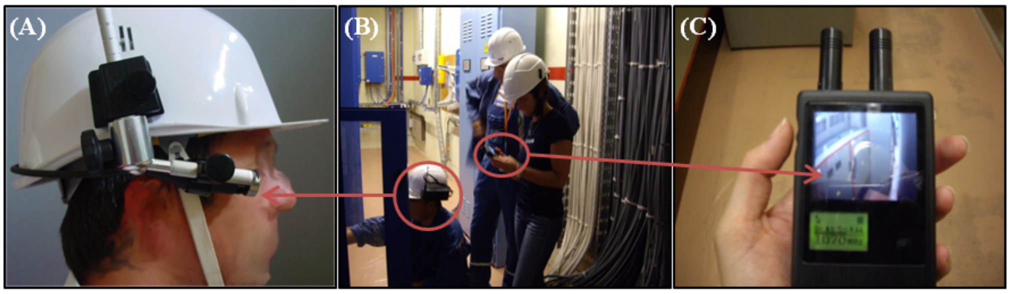


The same scene viewed from an external or third-person perspective (on the left) and from a first-person perspective (on the right).

45 For the third-person perspective view, a camera fixed on a tripod provided the contextual view of the setting. Given the physical constraints of the environment, the best location for the camera was selected in order to film the working environment, the machine and tools handled by the operator, and the operator himself.

46 This contextual recording occurred simultaneously with a second one, based on the paradigm of “subjective-evidence based ethnography” (Lahlou, 2011 ; Le Bellu & al., 2010 ; Rieken, 2013). This approach sought to capture the activity as it was perceived by the person who was experiencing the situation. To achieve this, the activity was recorded from the operator’s viewpoint, namely the first person-perspective, by using the subcam (subjective camera) (Lahlou, 1998), a small digital camera designed to be worn at eye-level by the subject performing the activity.

Figure 4. High-definition subcam attached to a hard helmet with its remote monitoring screen



47 Some high-definition subcams attached to hard helmets with a remote monitoring screen (figure 4) were especially designed for this study to cope with the constraints which arose from studying the manual activities (wide capture angle, visual quality, etc.) and from safety clothing and protective wear for power plant operators.

48 The use of customized first-person perspective recording tools such as the subcam (a.k.a. camera-glasses, headcam, head-mounted video camera, body-worn video, etc.) for studying a work activity is growing in the field of social sciences as well as in occupational training settings and even some extreme settings (Hodges & al., 2006 ; Myrvang Brown & al., 2008 ; Omodei & McLennan, 1994 ; Parker & al., 2007 ; Rix-Lièvre & Lièvre, 2010).

49 These embedded devices for operators provide practical advantages for practitioners and researchers who analyse work by facilitating the task of data collection. Indeed, the subcam enables activities to be captured while the subject is moving. Regardless of the location, the access to materials, or the type of body movements, the subcam inevitably follows the operator, providing a continuously situated recording of the operator’s activity. In this way, data is collected without an outside observer ; the operator is free to organise her/his activities and movements.

50 Furthermore, this device overcomes certain observation constraints due to natural affordances of the human body. Indeed, some physical elements (interactions mediated by tools) of the

environment can only be perceived by the operator because of her/his unique position in relation to the system (figure 3). This is typically the case for movements involving the operator's hands at the level of and close to the thorax area. Only an "immersed" view of the gesture can clearly show what is taking place, particularly in very small and confined places.

51 In addition to its practical aspects, the subcam also provides a unique perspective on the world : the first-person perspective shows how one experiences real-world situations. Among its numerous specifications (Le Bellu & al., 2009), the subcam was originally designed to be positioned very close to the ears, mouth, and eyes (Lahlou, 1998) so that the embedded system would automatically follow head movements and capture the operator's attentional and auditory flow. Thus, the perspective provided by the subcam not only captures motor actions but also provides insight into the subject's internal activity. Head movements, gazing, or hesitation are clues of the subject's intentions. Observations made about where the subject focuses her / his attention allows the researcher to be "in the subject's shoes" and to formulate assumptions about the subject's reasoning and future actions. Nonetheless, these assumptions might be mistaken, particularly if the considered activity is not within the realm of the researcher's knowledge and/or culture. For this reason, video data alone is not sufficient to determine the subject's cognitive path. It is essential to use verbalisation to collect the subject's commentary on her/his activity through simultaneous and/or *post-hoc* verbalisation protocols (detailed in the next section).

2.2.4 Verbal protocols of expert knowledge

52 Motor actions of a professional gesture captured by video devices cover only the behavioural dimension of the activity. These actions only make sense when related to the internal psychological components of the activity, namely goals and mental operations that, unlike physical operations, are not visible. It is therefore crucial to collect these elements. Moreover, the expertise embodied in the gesture lies in a series of decisions which are based both on one's way of perceiving and processing the situation, and on cognitive models that guide decisions. From a learning and training perspective, it is fundamental to access and collect internal data which affects reasoning since it allows apprentices to understand the underlying rationale of the gesture and greatly facilitates the internalisation of the knowledge required for the gesture's execution.

53 We used two verbalisation techniques adapted from the series of existing methods in the field of ergonomics and work psychology to enable a subject to talk about her/his work activity (Bisseret, 1981 ; Clot & al., 2001 ; Clot & Kostulski, 2011 ; Ericsson & Simon, 1984 ; Falzon, 1991 ; Gherardi, 1995 ; Leplat & Hoc, 1981 ; Oddone & al., 1981 ; Rix & Lièvre, 2008 ; Theureau, 2003 ; Urquhart & al., 2003 ; Vermersch, 2009).

a. Goal-oriented talking-aloud verbalisation protocol

54 According to the epistemological models of situated and distributed action, a subject is more likely to externalise and share knowledge at the moment (s)he is executing the task. From this perspective, situated and contextualised actions meet all the execution conditions of real activity, and constitute a "facilitator media" for externalising and accessing human thoughts and reasoning. We therefore used a verbalisation protocol simultaneously with the action in order to assist the externalisation of the tacit knowledge embodied in professional gestures.

55 The first time the simple spontaneous talking-aloud verbalisation protocol (Brommel, 1983 ; Ericsson & Simon, 1980 ; Flaherty, 1974) was applied was not satisfactory because, as previously shown by other authors (Leplat, 2000), only prescribed activity features were described. As a result, we provided the operator-expert with more precise instructions so that verbalisations would better emphasise the tacit dimension and her/his subjective reasoning. We thus added the "goal component" in the instructions and asked operators not only to describe their activity as they went along, but also to announce their goals orally before each specific step of the gesture and to explain "the why" and "the how." The general instruction of this goal-oriented talking-aloud verbalisation protocol (Le Bellu & al., 2009) was the following :

> "Express the purposes of your gesture. And for each one of these purposes, explain both the reasons underlying it and the way you intend to achieve it."

56 In addition, the operator was asked to verbalise good practices (knowledge developed over time, situations, experience, people met, etc.) and/or critical points (warnings about hazards or risks that are not formalised in any documentation) and that (s)he considered important to transmit to novices. Following a main Perceived Quality principle, the operator was free to select what (s)he considered necessary to comment on. This particularly applied to how (s)he broke down the activity and to what degree (the level of "fineness") ; for example, at what point the operator considered a specific action had started and had been completed.

57 Our field studies showed that the success of this goal-oriented talking-aloud verbalisation protocol depended on a mental preparation step carried out by the operator and which occurred before the simultaneous verbalisation protocol. The operator took the time to mentally prepare by considering how to explain the professional gesture *in situ* (with emphasis on aspects that are usually tacit) in a format that provided a cognitive model for the gesture and, later, a structure for educational material. This mental preparation step can be conducted in pairs between the expert and a fellow operator or another expert. We observed that discussions helped to share practices, to externalise knowledge, and to clarify the best and clearest way to explain the gesture.

b. Adapted individual and group self-analysis interviews

58 The individual self-analysis interview (Ginsburg & al., 1985 ; Pinsky & Theureau, 1987 ; Theureau, 2003 ; Von Cranach, 1982), the "allo-confrontation" interview (Mollo & Falzon, 2004), the group self-analysis interview (Clot & al., 2001 ; Clot & Kostulski, 2011), and the re-situ interview (Rix & Biache, 2004) are variants of subsequent verbalisation techniques which provide access to the operator's cognition after performing a professional gesture. Their aim is to immerse the operator *ex-post* in her/his own activity by confronting her/him with the video recording of her/his activity as (s)he verbalises her/his cognitive processes.

59 The particularity of the method that we applied is that it relies on the principles of the Activity Theory, the Perceived Quality Approach, and on the first-person perspective provided by the subcam. With our adaptation of self-analysis interviews, it was possible to obtain additional verbal information from the operator about the content of the activity's components (goals, tasks, actions, operations) and on the tools that were employed in her/his activity. The analysis of these subsequent verbalisations showed which tasks helped the operator to achieve her/his concrete goals, under which situations, using which tools ; and consequently, which actions and operations were carried out under these tasks. This interview made it possible to arrive at an accurate reconstruction of the subject's activity.

60 Overall, the self-analysis interview involved the operator viewing and commenting on the video (projected onto a screen) of her/his performance of the activity. Her/his commentaries were recorded and the interview was filmed. The analyst could then review the interview to determine what the subject was referring to during the commentary, which is quite challenging to understand with only an audio recording.

61 In addition to the video, a first cognitive model of the gesture (figure 2), based on the analysis of the collected video and audio material, was submitted to the expert for feedback. These two media, namely the video and the cognitive model of the gesture, were thus used to facilitate discussion and to verify the model and its components. At this point, the objective was primarily to ensure that the model, called the "*goal tree*" corresponded to what the operator wanted to convey. The data obtained subsequently contributed to the improvement of the cognitive model. This structure provided the foundation for educational transmission (see the Results section which follows).

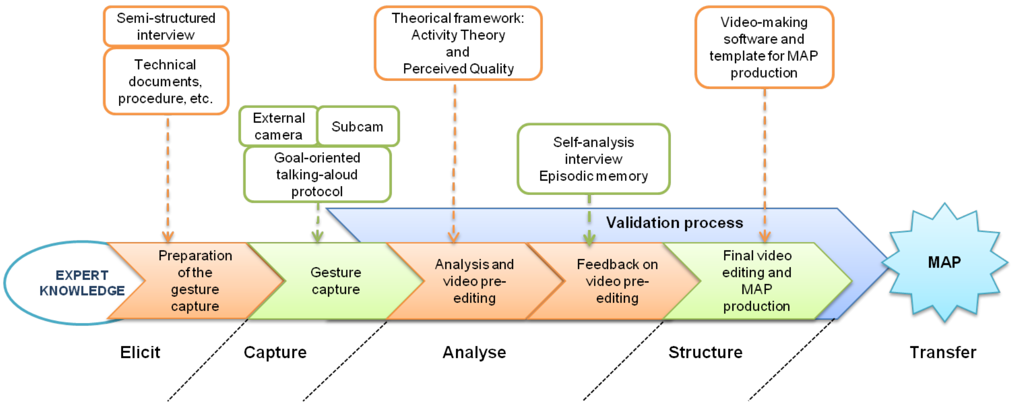
3. Results

62 This study resulted in the development of a knowledge capture process. Based on this method, a new kind of educational media for occupational training was also developed. This section presents these two results, as well as the main findings from the qualitative evaluation of the new training system based on the MAP, during real training sessions at the company.

3.1 ECAST Method for Eliciting, Capturing, Analysing, Structuring, and Transferring Expert Knowledge

63 The combination and application of the theoretical and methodological tools described in the previous section led to the development of a novel method for capturing and transferring tacit occupational knowledge embodied in professional gestures. Called ECAST (Elicit, Collect, Analyse, Structure, and Transfer), this method relies on a comprehensive approach to expertise management using a situated capture device. This process of expertise capture (figure 5) goes beyond capturing and preserving to enhance and effectively transfer collected knowledge through an educational media called MAP (Multimedia platform for APprenticeship).

Figure 5. ECAST Method for capturing and transferring expert occupational knowledge to novices



64 The objectives of each step of the ECAST method were the following :

65 Step (E) - *Eliciting* : this step concerned the preparation for the next gesture capture step of a work movement by collecting documents and running a semi-structured interview with the expert ;

66 Step (C) - *Capturing* : this was the audio-video capture of the gesture from the first and third-person perspective. It also included the mental preparation of the operator and the use of the goal-oriented talking-aloud protocol ;

67 Step (A) - *Analysing :* this step involved the analysis of the collected material and led to a cognitive model of the expert's gesture (the goal tree). The model and the video recording of the operator performing the gesture were then discussed during an adapted self-analysis interview ;

68 Step (S) - *Structuring* : this stage entailed the formalisation of all the previously collected data, the building of the MAP, and a validation process for the device at the operational, managerial, and educational levels ;

69 Step (T) - *Transferring* : this was the final step and it concerned the dissemination and use of the MAP in knowledge transferring situations, such as occupational training settings or in the field.

3.2 Multimedia Platform for APprenticeship (MAP), a new device for occupational training

70 Built on top of ECAST, the Multimedia Platform for Apprenticeship (MAP) was educational training software which allowed novices to learn the "how to's" of their work independently through the real-time experiences of experts.

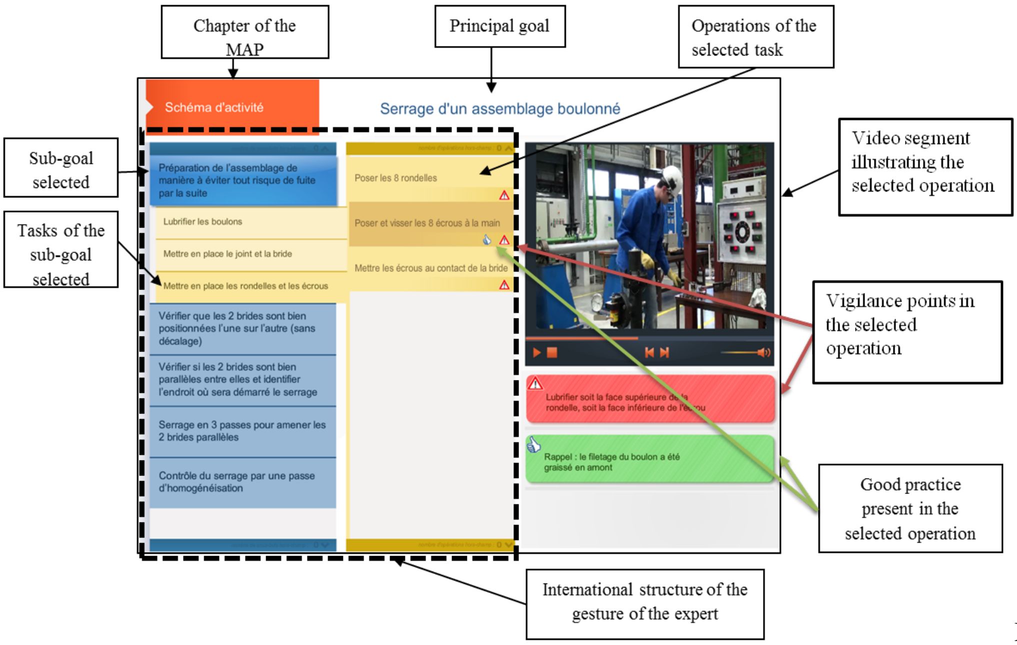
71 The MAP's originality lies in the way it modelled the occupational knowledge embodied in a professional gesture by exploiting data collected through ECAST. This included such elements as : subjective and contextual videos, experts' verbal comments, photos, charts, diagrams, and links to technical documents describing the procedure. All these resources were incorporated into a representation that enabled the apprentice to create and retain a mental model of the gesture.

72 The MAP was composed of three sections.

3.2.1 Section 1 : the goal tree

73 Section 1, the goal tree model (figure 2), represented the core of the MAP structure. This representation, based on Activity Theory and data collected during reconstruction interviews, provided the skeleton of the activity, particularly of the goal and sub-goal architecture. Data obtained with the Perceived Quality Approach was used to connect each sub-goal on the skeleton to concrete operations on objects in the environment. The video was broken down to the activity's most basic components, to the "finest" grain of the operations. Thus, each operation was illustrated by a video clip from either a first-person or a third-person perspective or from an edited version of both of these views. This video clip included the commentary of the expert. The learner could therefore learn the professional gesture step-by-step, by "walking" through the goal tree section at her/his own pace (figure 6).

Figure 6. An example of the "goal tree" section integrated in the MAP



Moreover, some good practices and vigilance points necessary in a good quality gesture were identified and emphasised by specific icons in the MAP. The expert's good practices and tricks of the trade corresponded to the subtleties of a professional gesture developed by the expert through experience and over time. In the MAP, they were pointed out by one "thumb up" on a green background. Vigilance points are complex and challenging ; they require increased attention because experts consider them necessary for the smooth running of the activity. It is essential to acquire skills to manage them for the successful and safe performance of the gesture. Vigilance points are represented in the MAP by a red and white triangle with an exclamation mark in the centre set on a red background.

3.2.2 Section 2 : the "full video"

74 The second section in the MAP was called "full video" (figure 7). It gave an overview of how to carry out of a professional gesture (from start to finish) without any interruptions. This video had commentary, from both the first-person and third-person perspectives, and it provided textual data corresponding to sub-goals, tasks, good practices, vigilance points, and possibly some images (diagrams, pictures, etc.). In this MAP section, the operation/action level was not taken into account. This resource was available in two forms, either as a stand-alone video which could be viewed on several electronic devices, or as a section in the MAP software.

Figure 7. The stand-alone video form of the "full video" section

3.2.3 Section 3 : the "silent review"

75 Finally, a third resource, called the "silent video review" showed the completion of a professional gesture without commentary and at regular speed. It allowed the apprentice to (re)view the gesture without any additional explanations so that (s)he acquired the rhythm of the activity and learnt to focus only on the physical operations and the sounds of the tools and machines. This section was used either to discover the activity or review a gesture once it was learnt.

76 Thus, this structured multimedia is not comprised of only one video. Rather, it is a way of presenting a gesture's essential points as captured from the expert's point of view so that the apprentice can see the psychological aspect of the movement. This structured multimedia responds to the organisation's and the trainers' request for an innovative, digital support for training, while improving tacit knowledge transmission in apprenticeship. It would not replace real occupational mentoring practices, but in cases where it is no longer possible, it would provide an overview of the know-how that would have been transmitted from an expert to an apprentice.

3.3 Evaluation of the new training system

77 After giving an overview of the way the MAP was incorporated in the real training session, this section summarises the main observations and findings, first from the apprentices (A) viewpoint, and second from the trainers (T).

3.3.1 Incorporation of the MAP in the training system

Figure 8. The MAP-based training system

(A) Use of the goal tree section in pairs. (B) Use of the full video section. (C) Use of the silent review section. (D) Performance of the professional gesture by apprentices during the practice session, after learning with the MAP

78 It was agreed that the incorporation of the MAP in the training process must by no means disturb the educational course of the training session. We allowed the trainers the freedom to use the MAP as they wished.

79 ***Use of the goal tree section.*** The trainers chose to have the trainees work on the MAP in pairs. They gave them forty-five minutes to explore the goal tree section at leisure, during the first half-day of the course. The trainers first explained to each pair how to use the software, and then let them examine the goal tree with the videos and take notes (figure 8A).

80 ***Use of the full video section.*** The full video section was used by the trainers as a recap tool, that is as a summary at the end of the first day after the theoretical afternoon session (figure 8B). During the second day, the trainers referred several times to the video to draw on the visual memory of the trainees and thus help them to get a better understanding of the messages the trainers were trying to communicate.

81 ***Use of the silent review section.*** The trainers decided to use the silent video review during the morning session of the second day to build a bridge between the theory studied the previous day and the practical exercise that would follow. The trainers called this the "*capitalisation* (informal assessment) session".

> A silent review can be quite nice during the capitalisation session. You run the video in the middle and you stop when and where you want. There, what is he doing there ? You can already see the method. Afterwards we can say : "There, he's placing a seam. What are the pressure, temperature characteristics ? We wrote it down by hand on the side. like that, during capitalisation, that can help." **[I1]**

82 The trainers projected the silent video on the board and used it to have the trainees recapitulate what there was to know about the tightening gesture (figure 8C). It was one of the trainers who played the video and stopped it whenever he wanted to ask the trainees what they remembered. Used in this way, the video allowed him to scan all the points to be studied and to make the session more dynamic.

3.3.2 Perception of the MAP-based training system by the apprentices

83 All the trainees agreed that using videos in training was both interesting and necessary. No one felt that they were not useful.

> A. I think it's become a necessity. **[S-Q2, A6]**
> A. For technical training courses like that, it is undeniably a plus, in particular for those people who've never done the actual work. For those people who have already put the gesture or activity into practice, the issue is to know whether people will buy in [to this approach] or not. **[FG2]**

84 They considered videos to be an effective medium for creating links between the theory taught in class and the practical execution of a gesture. Moreover, the images enhanced comprehension and learning.

> A. Makes it possible to properly see, in a classroom setting, a technical gesture described theoretically a few minutes earlier. **[S-Q2, A5]**
> A. I liked it because it enables you to put an image to the technical gestures. **[S-Q2, A1]**

85 The use of the first person perspective was also appreciated by the apprentices.

> A. It was interesting to see the first person expressing himself […]. If the camera goes directly outside, it is not possible to see exactly what the person is doing. **[FG2]**
> A. What I found interesting was the use of the camera to show exactly what the person was doing. **[FG2]**

86 Overall, the trainees wanted to bring the full video or the MAP with them to the production sites.

> A. Will we have access to the software at a later stage ? For example, to review, to remember how it goes. After six months, we will only dimly remember. **[FG2]**
> A. Would it be possible for participants to receive this aid at the end of the training ? As far as I am concerned, I know I will not have any more training for another two or three years. However, if I had this tool, e.g. on CD-ROM, and if I consulted my notes, I would be able to recall the gestures I will need. **[FG1]**

87 Bringing the full video and the MAP would enable them to recall and recap a gesture before going out into the field.

> A. These are things one can use prior to an assignment to a somewhat specific thing, task with something at stake. **[FG2]**
> A. Before going on assignment, to remember things again. On the other hand, I would not go and consult the tool like that. I would really need to need it ! **[FG2]**
> A .Seeing the video again is faster and more meaningful than going through the whole thing again. As Compared to a [training session] folder, the video will enable faster recall. **[FG2]**

88 The trainers noticed that trainees memorised the information well when it was presented with the MAP. This was also the feeling expressed by the trainees.

> A. That is, during the training, or from the moment one has seen the film, one has heard certain information, one remembers either consciously or unconsciously, and when one sees the film again like that, that information rises to the surface again. Not all of it, but there is quite a lot that comes back. **[FG1]**
> A. We cannot remember everything … This tool could be a good safety net. **[FG1]**

89 The trainees once again emphasised their interest in having images so they can "see how it's done" rather than only "hearing" theoretical, oral explanations given by the trainers. They see the MAP as a complement or a means of summarising the essential parts of a professional gesture, which is indeed consistent with the design objective of the MAP, namely, to emphasise the most relevant components of the gesture to be learnt.

> A. It's a good complement. there are things I, personally, saw in the movie, which I had not noticed during the training. **[FG1]**
> A. […] when we see it, it's better than the oral version. **[FG1]**
> A. I get the impression that we see that which is essential, and it's summarised. **[FG1]**

90 The trainees like the goal tree section, which gives them the option of reviewing the more complex points of the gesture as often as they would like.

> A. The advantage of the video is that one can replay the passages one doesn't understand all that well. **[FG2]**
> A. The fact of having individual access, allows you to watch the gesture you have trouble interpreting several times over. **[S-Q2, A8]**

91 Furthermore, the various terms (the chronology (A1), the details of the professional gestures (A2), the step-by-step breakdown (A6), structured videos (A7)) used by the trainees to answer the following question : What did you like about the MAP ? show that the breakdown and structuring of the gesture into goals, tasks, operations, etc. was a real advantage. Two of the trainees particularly liked the fact that this could be adapted to their own learning speed :

> A. The rate at which the information is provided matches our rhythm, supported by videos. **[S-Q4, A3]**
> A. […] allows you to take notes at your own speed. **[S-Q5, A8]**

92 All participants were satisfied with the use of the silent video review in the *capitalisation* phase.

> A. Good support. You can see the gesture and the trainer contributes to understanding the theory. **[S-Q12, A3]**
> A. Enables faster memory reactivation of the knowledge acquired the previous day. **[S-Q4, A8]**

93 Overall, the trainees were satisfied with the summary provided by the use of the full video at the end of the first day. It seemed to provide a good way of recapping what had been studied through images. The trainees thus left with a summary of the key points of the tightening gesture.

> A. Interesting. It's a booster for the information acquired during the day. **[S-Q13, A1]**
> A. Summarises and cleanly finishes off the day. **[S-Q13, A5]**

94 Only trainees who already knew the gesture before taking part in the training considered that the amount of video (shown three times) as compared to the duration of the training (one day and a half) was too much and that the gesture was oversimplified.

> A. It soon becomes obvious that there are always the same sequences. I knew we would go back to the things we had available. I know that I tend to have a good visual memory, so I wondered about that. When seeing the same thing again, I had a little trouble getting attracted. **[FG2]**
> A. that one, that of the morning and that of the end of the day. Over a training that spans three half days, this can perhaps be a bit much. Three videos over one week, that could be ok. **[FG2]**

95 However, this opinion was held only by trainees who already had knowledge of the gesture before participating in the course. For those who had no previous knowledge, the information did not seem superfluous.

> A. We are not familiar with the gesture. You are, but we are not. **[FG2]**
> R. So you found it less repetitive ? **[FG2]**
> A. Yes. **[FG2]**

96 This feedback shows that participants have a strong educational interest in the MAP. All the same, the MAP must not replace training …

> A. This must not replace training courses. The risk is that employees may simply be sent to the media library on the assumption that that will suffice. **[FG1]**

97 … and the trainees must remain aware of the differences between the gesture shown in the MAP (performed by one trainer in the training centre) and the same gesture as it should be performed in the field.

> A. This is presented under ideal conditions. In the example, you can turn all around the machine. We are told to pull the wrench but in real life sometimes you can't. Sometimes you have to push because there is no other option. **[FG2]**
> A. It's a good thing to use the theory to find the perfect gesture, but in reality the conditions are not always perfect. But the gesture must be perfect. If not, things will go downhill. That's human nature. **[FG2]**

3.3.3 Perception of the MAP-based training system by the trainers

98 The MAP was perceived as a time saving tool with a common language that made up for the fact that there could be several different trainers working on the same training course :

99 *T. It creates a common language among all those people [trainers and trainees] […] As a result we save* time. [I1, T2]

100 The MAP used in teams of two seemed to encourage the participation of all the trainees, provided support for the trainers, and helped them to better define and discuss specific problems. Trainees asked questions more spontaneously because they were able to browse videos (and other resources) at their leisure and to review them as often as necessary. It thus made it possible to identify the difficult areas that led to questions.

> R. Do you, for your session, find it helpful ? Or, rather, is it something that is not pertinent ? **[I1, R]**
> T. Oh yes, it is. In Particular, the fact of sending them off in several groups. In a training, you can't necessarily, easily, stay with one person. As far as the method is concerned, this provides a bit of relief. Like that, each little group can have its own idea. They can go back to the material if they don't understand. There isn't that reluctance like when they are all together in one group. Sometimes there is someone who doesn't understand […]. They don't necessarily dare to ask you to explain again so as to not be taken for an idiot… At least that's the impression I got. **[I1, T1]**

101 It was the first time the trainers had their trainees work in pairs. They stated that using the MAP as an aid in small groups made those who did not understand and did not dare to ask questions less inhibited :

> T. … there are some people, especially in this group, who were quite shy. [They] won't say anything for fear of saying something stupid. They are afraid of being the only ones who do not know. Like that, By the fact of putting them into small groups, they are with just one other person. If there's something they didn't see, they go back to it. As a result, they don't come to ask me. They simply replay the video and understand it all by themselves. There is no longer that aspect of "I don't feel like looking like a total nitwit in front of my colleagues and the trainer". **[I2, T2]**

102 On the other hand though, distributing them into small groups encouraged personal interpretations which were made too hastily and that were not always right :

> T. When you have a group in front of you, you can see who has questions. Whereas in this configuration you are behind two people but you do not see the others.
> And, I've heard comments about, among other things, the three tightening steps [...] I was behind a group that was saying "That's useless, that's no good". If I hadn't been behind them [at that moment], I would not have heard them. That's the caution I would express. **[I1, T2]**

103 The MAP was perceived as being a real help for trainers. They used it to support the range and intensity of explanations and make the training session more dynamic :

> T. What I like about using the MAP is that it "reroutes" the session. It gets things moving. It lightens the load on the trainer. In fact, for half an hour you're there as supporting cast. You have nothing to explain, the explanations come all by themselves. Once again, Several times this morning, if they had not understood the first time around or not seen everything, they played it back. On the other hand, if you're the trainer, you must kindly take account of this attention deficit. **[I2, T1]**

104 The image-based nature of the MAP made it possible to illustrate and support the trainer's oral explanations :

> T. On top of it, we are showing them their trade, their job. We don't give them a speech, we show them. I think it's more pleasant and enjoyable as situations go. **[I2, T1]**

105 Both trainers noted they saved time on the sequences for learning gestures.

> T. In terms of memorisation, last time they were given a written tightening method. Therefore according to people, it will more or less count. There, This time, they all saw the gesture at least once, so in fact, instead of attaching to sentences and imagining what they would do, they directly related to the images. So, I think [that's why] they had more initiative to go ahead and execute the gesture. This is why, in the group of five, everyone did something ... They were not focused on the method in itself ; they did not say "Ah, how do we do this ? How do we do that ? "... I even put two dynamo-keys, and they tested them. They had fun. **[I2, T2]**

106 Finally, an improvement in the practical session (figure 8D) was noted. Greater speed in the gesture's execution was observed by both trainers. The gesture was performed twice during the session with the MAP, while only once during the session without the MAP.

> T. It went much faster ! Last week, we did only one tightening ; while there, they[the trainees] had not even brought their procedure manual [The trainer said later to the analyst that, in fact, one of the apprentices had brought the procedure, but it was folded up in the back pocket of his pants and he did not use it]. You saw, regarding the gesture, that they didn't necessarily ask questions and they performed it... And we hadn't changed a single thing in the course compared to the week before. **[I2, T1]**

107 In brief, the structural and visual features of the MAP seemed to facilitate memorization and comprehension of the professional gestures. However, even though the data provides evidence that learning improved, we must remain cautious. Only more extensive testing over a larger number of training sessions will provide robust conclusions about learning. Variables and parameters to be monitored should be identified in order to design an evaluation protocol that assesses the knowledge acquired, ideally in the short, medium, and long term.

4. Discussion

4.1 Methodological findings

4.1.1 Video ethnography and the first-person perspective

108 The hypothesis of this research was that the design and use of tools using video techniques, especially from the first-person perspective, could facilitate the collection and transmission of knowledge embodied in occupational practices. The subcam adapted to the working conditions of the industrial plants turned out to be both : 1) an instrument for observing and analysing human activity *in situ* (for research purposes) ; and 2) an instrument responding to a real-world operational problem, namely capturing the knowledge underlying work gestures (for occupational training purposes). From this viewpoint, the results show that our method contributes significantly to refining work analysis and enriching training methods in a high-risk industrial environment context.

109 Use of a first-person perspective device enabled the analyst to have a comprehensive view of the activity while reducing the cognitive and temporal resource costs for the subject and partially overcoming the inconveniences caused by an outside observer's presence. From the standpoint of capturing professional gestures, it was nonetheless essential to combine the two capture modes (first and third-person perspectives) concurrently in order to approach a “total visibility” of the gesture. The way both perspectives were mixed depended on what we wanted to demonstrate to the apprentice during the training sessions.

110 Furthermore, the first-person perspective provided by the subcam allowed a view of the gesture such that the viewer felt (s)he was sharing the expert's field of perception and partaking in the activity. This immersive perspective puts the viewer in a position “get right involved”, which can greatly encourage active learning and the embodiement of gestures (Le Bellu et al., 2010 ; Rieken, 2013). This characterictic was explored in the design of the MAP which aimed to construct a learning strategy that went beyond observation and imitation (Rizzolatti & Craighero, 2004). Indeed, depending on whether the third- or first-person perspective was chosen in the video editing, the learner was in the position of the spectator (the third-person perspective), which helped in the understanding of the context, or (s)he was in the position of the doer of the gesture (the first person-perspective). This latter perspective allowed the novice to identify with the expert and to project her/him-self into the action being performed. Consequently, there was a greater cognitive involvement of the learner.

4.1.2 Goal-oriented talking-aloud verbalisation protocol

111 The goal-oriented talking-aloud verbalisation protocol that we developed included : (1) an introspective dimension : what are the subject's goals ; (2) a descriptive dimension : how does the subject want to achieve her/his goals ; and (3) an explanatory dimension : why does the subject choose to act in a certain way. This protocol, although demanding, gave the researchers

access to the cognition of the gesture by providing the underlying logic of an expert's gesture in order to avoid simple imitation by a novice.

112 Although "the how" of the professional gesture was schematically reduced to the external side of the activity, namely the operation layer (see figure 2),it is worth noting that in spite of their visible feature, manual operations can also be hard to explain : beyond the why, words can also be poor in explaining the how. This is particularly true as regards of tacit knowledge, notably for embodied know-how that involves detecting and perceiving information, appraising measures and distances with the naked eye, determining the force to be applied on a tool, etc. Consequently, viewing videos of these operations partly would seem to contribute to filling in the verbal gap. It also provides clues as to why, whatever the occupational training devices, these videos can only complement occupational learning and why they must be thought up and implemented in conjunction with an actual bodily experience by the novice so that she/he may feel, construct, and embody her/his own gesture.

113 One issue that may be raised is the bias induced by verbalising. Indeed, the desired result was achieved, since the activity was orally pre-structured according to the goals identified and pursued by the operator. One may nonetheless wonder if orienting the protocol in such a way might not have introduced a bias in the operator's representation of her/his activity. Was the emerging mental model actually prototypical of such a gesture ? Did thinking in terms of goals affect the performance of the gesture ? Did it disrupt the acquired automatic reflexes ? While it is certain that one can deviate from the actual activity, it has also been shown that this kind of instruction directing the subject to explain her/his actions can positively modify the activity by contributing to enhanced performance (Bisseret & al., 1999). Moreover, despite the well-known drawbacks of simultaneous verbalisation, in particular slowed performance, we obtained quite satisfactory results concerning the externalisation of tacit knowledge by using this protocol, making this slower performance acceptable. The structured verbalisation provided a way to access the internalised knowledge of the expert (what (s)he had in mind) and, most importantly for this case study, it allowed us to prepare for the analysis of the gesture when the capture phase started. Nonetheless, we tried to compensate for the disturbance caused by commenting on the gesture by capturing the raw movement (i.e., without any operator commentary) before the mental preparation and collection phases. By so doing, the gesture was not yet influenced by an intentional structuring and the gesture's pace was not disturbed by the operator speaking. This recording was used for the MAP's silent review section.

4.1.3 Adapted self-analysis interview

114 Due to the hazards and the constraints of the actual work place, it was not always possible to conduct an interview with the operator who executed the gesture (significant time pressure and limited availability in the production industry). Experiments with different practices (see Table 2) showed that the self-analysis interview could be run in cooperation with specialists other than the operator who was filmed or with an expert-novice team, if the initial operator agreed to have her/his video viewed by others. Working with an expert-novice team enabled an exchange of opinions and more easily pinpointed the various knowledge that the experts had gained over time and, conversely, the difficulties arising from a lack of experience or practice. This subsequent verbalisation method could also be run with a group of experts. The possibility of using these different variants of the technique creates a more flexible operational device.

115 Furthermore, when compared to a third-person point of view, we noticed that the subjects' ability to recall the reasoning underlying her/his movement when viewing a first-person perspective provided by the subcam was much more precise and detailed. The hypothesis of first-person perspective as a trigger for episodic memory probably contributes to an enhanced recollection (Conway, 2009 ; Lahlou, 2011) and could explain the improved quality of the verbalisations that we observed during the self-analysis interviews. Moreover, we adapted the self-analysis interview to resemble a "subject-oriented" interviewing technique in which the analyst created an environment where the subject could explicitly express her/him-self. The essential difference between a conventional post-hoc verbalisation protocol and ours was in who led the discussion. In the case of the conventional protocol, it is the analyst who speaks, gives direction, and asks questions, while in the self-analysis protocol used in this research

it was the subject performing the activity ; (s)he was in control of replaying the first-person perspective (essentially) video and making comments when necessary. This technique was called "Replay Interview" by our research team (Lahlou, 2011 ; Le Bellu & al., 2010 ; Rieken, 2013). In this way, the subject becomes a veritable collaborator with the researcher, as (s)he is asked to reflect deeply while analysing her/himself. Even though it was not the primary goal of this research, this type of method, in either the collective or individual case, was beneficial for the subjects' self-analysis and activity improvement (Fleck & Fitzpatrick, 2009 ; Gillespie, 2007 ; Schön, 1983 ; Suchman & Trigg, 1991).

4.1.4 Methodological impacts

116 From a methodological point of view, we adopted a non-traditional position to that which is usually taken in work analysis : rather than collecting data and then analysing it consecutively, we completed these stages concurrently owing to the very active participation of the subjects. Indeed, compared to existing approaches, ours differed particularly in its use of a collaborative style of analysis where the expert was regarded more as a colleague than as a subject. We took advantage of her/his proficiency to help (1) formalise her/his cognitive model and, in turn, (2) demonstrate this model in the most effective way through the video. We reconstructed the logic of the gesture with the expert so as to enable novices to understand and internalise them. However, the likelihood of this upstream, in-depth analysis being effective depended directly on the verbalisations collected, which were influenced by the context and the ability of people to comment during the capture stage of the gesture. Depending on the quality of the talking-aloud verbalisations, the self-analysis interview was used either (1) to complete and validate an upstream analysis, or (2) to fully investigate the activity. Environmental settings such as the training centre used for data capture were more suited to the first function because the situation, the environment (less noisy, less time pressure, etc.) and the verbalisation protocols (trainers were more used to explicit knowledge) were more easily controlled. On the other hand, protocols run in real environments and work situations (e.g., power plants) were more appropriate for the second purpose of *post-hoc* investigation. Our experiments demonstrated that both could be accomplished. Nonetheless, while studying the activity in the training centre did not include all the real constraints often encountered (noisy and dark environments, difficulties in accessing certain machines and materials, stress…), it did provide more time and more precision to capture the gesture. This allowed advanced verbalisation protocols to be conducted and, consequently, the possibility to make several recordings. This made it more suitable for producing educational resources.

4.1.5 Impact on externalisation and internalisation processes of knowledge

117 We attempted to render the tacit dimension of professional gestures explicit through a triangulation process (Denzin, 1978) that used different types of data and methods. The ECAST method enhanced memory by helping experts recall and become aware of automatic reflexes and reasoning processes that they had developed over time and through experience. This method was not a simple collection of knowledge but rather an externalisation of it (from tacit to explicit) (Nonaka & Takeuchi, 1995) by an *in situ* (re-)construction of embodied expert know-how. In future research, the MAP could be enriched by diversifying the 'references' to gestures. One way to address this problem would entail providing a range of cases showing the same gesture described by different experts, in different contexts and situations. This would help the apprentices to become much more aware of the diversity of practices so that they could subsequently comprehend and embody a work movement, and thus build and internalise their own "style." The development of a community platform, as a support for the ECAST application, which is based on the principles of communities of practice (McDermott, 1999 ; Wenger & Snyder, 2000 ; Wenger, 1998) could meet the need to diversify references to the gestures (Le Bellu & al., 2014).

4.2 Limitations

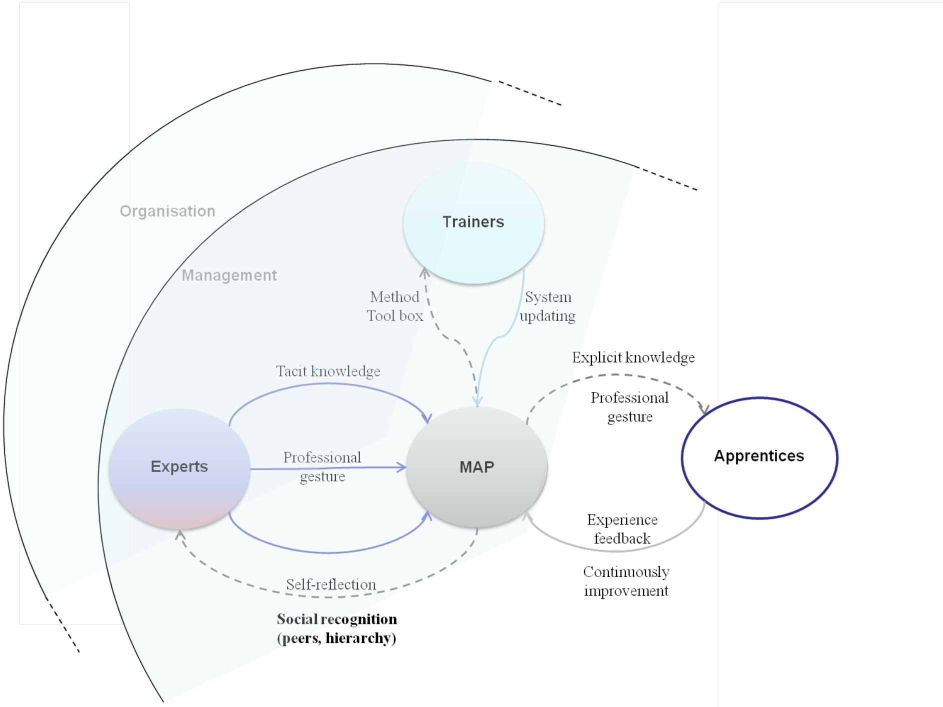
118 Experimentation with the capture protocol conducted in two fields (training centre and power plant) demonstrated the need to adapt the collecting process to the type of professional gesture

and therefore to the setting. We must be aware that every situation where a gesture is performed is different, each person having his/her own characteristics, and therefore each gesture is unique. Nevertheless, it is possible to categorise them according to a wide range of dimensions (Le Bellu & Le Blanc, 2012). The current state of this method is well suited to certain gestures, especially sequential and motor gestures, but more complex gestures require further work. This is particularly the case for collaborative gestures and for gestures requiring decision-making and synchronised operations. The current techniques did not allow a proper consideration of tasks distributed over time and between individuals.

5. Conclusion

119 The training system presented here, which was based on ECAST and the MAP, has taken a new look at the traditional training practice of occupational mentoring. We have shown that it is possible to develop methods for preserving experiential knowledge, for enhancing it, and for developing conditions that favour asynchronous sharing between retiring experts and arriving novices.

Figure 9. The socio-technical training system based on ECAST and the MAP



Contributions are represented by solid arrows, whereas benefits acquired are identified by dotted arrows.

120 This system focused on the individual. Three groups were directly involved in its implementation : experts, trainers, and apprentices. The system thus developed was one in which everyone benefited (figure 9).

121 The motivational and recognition factors were the keystones of the device and were essential to the proper functioning of the system ; experts, trainers, and apprentices were both users and contributors.

122 The application of ECAST allowed experts to “transfer” their know-how. This provided the means to at least partly access the tacit and formal part of the knowledge necessary to carry out certain professional gestures. The participating experts were in turn recognised by their managers for their expertise in a given area and were acknowledged by their peers. Their know-how, which was developed, shaped, and accumulated over the years, was publicly acknowledged. Consequently, the experts had a positive perception of their participation in the training program. They felt that they were leaving their mark on the company.

123 Through this approach, trainers and the company now have a method to formalise very specific gestures in a video-mediated format. This has met their need for innovative training solutions. In addition, the MAP gathers together several resources in one place : goal tree navigation,

detailed structured videos, silent video reviews, vigilance points, and good practices which provides a "toolbox" allowing trainers to customize their training sessions according to their needs, their trainees, the time available, the targeted educational objectives, etc. Using the MAP, apprentices can now learn how to perform certain professional gestures in a surer, more confident way.

124 In summary, the situated nature of expert knowledge is a key element for accessing an expert's tacit knowledge. This study has provided a novel method for collecting, analysing, modelling, and transferring explicit and tacit know-how embodied in professional gestures. The secondary result, based on ECAST, was the development of an innovative educational resource, called MAP, for occupational training purposes.

125 This comprehensive device relied on various collection techniques intended to help experts gain awareness of their tacit and embodied knowledge *in situ*. It used methods belonging to visual ethnography, ergonomics, and work psychology to address knowledge management challenges. Our method operationalized the Activity Theory and the Perceived Quality Appraoch by making it possible to analyse objective and subjective data. This data was collected through a double video recording device, one providing a third-person perspective and the other, the subcam, capturing the first-person perspective of the expert. These perspectives were combined with two specific verbal protocols, namely a goal-oriented talking-aloud verbalisation protocol and an adapted self-analysis interview. These different tools and frameworks were combined so as to recreate, as nearly as possible, the expert's subjective experiences and then to pass them on to the novices through the MAP.

126 After a positive evaluation of this new training system under real training conditions, the company in which the research was conducted decided to industrialise the method and the MAP. The ECAST method has been used by the company in the design of more than fifty MAPs and others are planned for the near future. This demonstrates the proposed method's usefulness for tacit knowledge capture and transfer, and its ability to be transmitted to other practitioners. Management in industry is now aware and concerned by this knowledge management issue. However, this is not just the case for the company involved in this study. Indeed, because of the international dimension of the current demographic transition, this is a societal challenge involving most organisations. Furthermore, many other contexts and fields of application for the method presented here could be considered : marketing, management, consumer psychology, and minority inclusion are just some such examples.

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Droits d'auteur

Résumés

Mass retirement in the baby-boomer generation has led to the current challenge of renewing mentoring in skilled trades, which have traditionally made it possible to transmit the know-how required in manual expertise. A study conducted with France's largest electricity supplier investigated how the combination of Activity Theory, video ethnography, and psychological verbalisation methods can help to enhance both the preservation of knowledge capital and occupational training. The study led to the development of a novel method for capturing and transferring tacit and explicit knowledge embodied in professional gestures of experts through the building of a new kind of educational media for occupational training. This device, called MAP, allowed operators to learn directly through the real-time experience of experts. A qualitative evaluation of the device showed an improvement in training. These results convinced the company to adopt the device for institutional use. This demonstrates the proposed method's usefulness for tacit knowledge capture and transfer.

Apprendre les secrets d'une profession au travers de l'expérience temps-réel des experts : capturer et transférer aux novices les savoirs professionnels tacites d'expérience

Les départs à la retraite en masse de la génération baby-boomer ont mené au challenge actuel de renouvellement des pratiques de compagnonnage professionnel qui, traditionnellement, permettent la transmission des savoir-faire incorporés dans l'expertise manuelle développée avec le temps par les experts. Une recherche menée au sein du plus grand producteur français d'électricité a investigué comment la combinaison de la théorie de l'activité, de méthodes d'ethnographie vidéo et de méthodes psychologiques de verbalisation peut aider à améliorer à la fois la préservation du capital de connaissances et la formation professionnelle aux gestes métier. Cela a amené au développement d'une nouvelle méthode ECAST, dédiée à la capture et au transfert des connaissances tacites et explicites incorporées dans les gestes professionnels des experts, et aboutissant à la construction d'un support didactique pour la formation professionnelle. Cette ressource, appelée MAP, permet aux opérateurs d'apprendre directement au travers de l'expérience en temps réel des experts. Une évaluation qualitative du dispositif a montré une amélioration de la formation. À la suite de ces résultats, le dispositif a été industrialisé par l'entreprise. Cela démontre l'utilité de la méthode proposée pour la capitalisation et la transmission des connaissances tacites.

Aprender los secretos de una profesión a través de la experiencia de los expertos, en tiempo real

La jubilación en masa de la generación conocida como baby boomer ha llevado al actual reto de renovación de las prácticas de acompañamiento profesional, que tradicionalmente permitían la transmisión de conocimientos tácitos (saber-hacer) incorporados en la experiencia manual desarrollada con el tiempo por los expertos. Una pesquisa realizada en el seno del mayor productor de electricidad francés ha investigado cómo la combinación de la teoría de la actividad, los métodos de la etnografía de vídeo y métodos psicológicos de verbalización, puede ayudar a la vez a la preservación del capital de conocimiento como a la formación profesional de gestos profesionales. Esto llevó al desarrollo de un nuevo método de ECAST, dedicado a la captura y transferencia de conocimiento tácito y explícito incorporado en los gestos profesionales de los expertos, lo que condujo a la construcción de un soporte didáctico para la formación profesional. Este método, llamado MAP, permite a los operadores de aprender directamente a través de la experiencia en tiempo real de los expertos. Una evaluación cualitativa del dispositivo mostró una mejora en la formación. A raíz de estos resultados, el dispositivo ha sido industrializado por la compañía. Lo que demuestra la utilidad del método propuesto en la capitalización y transmisión de conocimiento tácito.

Entrées d'index

Mots-clés : transmission de savoirs tacites, geste professionnel, ethnographie vidéo, protocole verbal, théorie de l'activité
Keywords : tacit knowledge transfer, professional gestures, first-person perspective video ethnography, verbal protocol, activity theory
Palabras claves : transmisión de conocimiento tácito; gesto profesional, video profesional etnográfico en primera persona; protocolo verbal; teoría de la actividad