Psychological and Behavioural Science

PhD Thesis

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TITLE:

Competencies, activity analysis and occupational training:
An innovative approach with full-scale simulators in high risk industries

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Declaration

I certify that the thesis I have presented for examination for the MPhil/PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I declare that my thesis consists of 100856 words (excluding table of content, bibliography and appendices).

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Abstract

Dealing with the social phenomenon of the "skills drain"[1], retired workers leaving companies *en masse* sometimes even before the recruitment of newcomers and consequently impeding classic training through mentoring, managers are seeking innovative solutions to train new employees and ensure a satisfactory level of competencies, especially in high risk industries. This led to questions to which the present research offers solutions: How are competencies of experienced workers mobilized? How can they be accessed? How are they developed through training? And more especially in full-scale simulation, which is key to occupational training in high risk industries.

The literature shows that the relationship between knowledge, know-how, skills and competencies remains unclear. A model is suggested, adapted to the present issue. It shows that competencies must be investigated in action through work activity analysis and leads to an approach to describe competencies in action, as in Le Boterf's model (1998), which presents a relevant link between competencies and action and was tested in the field. However, its application revealed a dearth of the expected description; pre-tests led to adapt it into a new model and protocol: the Square of PErceived ACtion (SPEAC model). The protocol was used, in the line of Subjective Evidence-Based Ethnography (SEBE) methods, to structure the replay interview following the recording of the workers' activity by subcams, miniaturized cameras mounted on spectacles (first person perspective). The resulting analysis was applied to full-scale simulation and in real operating situations for which a risk assessment protocol whilst using SEBE equipment was developed, tested and applied. It provided more relevant input data for occupational training, and showed higher performance in training than other methods (more exhaustive and less costly). In order to evaluate the impact of SPEAC-improved training on actual performance at work, the SPEAC improvement in a standard training curriculum was tested in two contexts of high risk industries (medicine and nuclear). In doing so, we tackled also the issue of resistance to innovation in training. The application of the SPEAC method to provide input data and to structure the training sessions improved significantly the work performance both at the end of the training sessions and in real operating situations.

When combined with improved pedagogical methods in simulation training, the SPEAC protocol has been shown to provide substantial gains for following real operating situations, both in terms of safety (fewer subsequent complications and less pain for patients in hospital, higher levels of reliability for activities in nuclear industries) and in terms of cost (per year, potentially tens of thousands of euros could be saved in hospitals when considering one operation and several millions of euros for a nuclear power plant when all activities are taken into account). Top management now wishes to roll out the method within their professionalization program in the two institutions where the field experiments and applications were carried out. In parallel, as a theoretical perspective, developments and applications in the framework of the present research have suggested the relevance of a systemic approach of the professionalization cycle in complex socio-technical systems: the Experiential Learning Theory-based excursive cycle of the professional training process developed in this study might contribute towards modelling a systemic approach of simulation training in high risk industries providing areas for improvement and consequently higher performance.

[1] "skills drain" not to be confused with "brain drain".

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CONTENTS

TABLES

FIGURES

The following images have been redacted as the copyright is owned by another organisation.

Page 28, Map 1.1, Map 1.2
Page 29, Map 1.3
Page 70, Map 3.1
Page 92, Map 4.1, Map 4.2
Page 106, Map 4.4
Page 127, Map 5.1
Page 132, Map 5.2
Page 135, Figure 5.1
Page 148, Map 5.3
Page 174, Photographs 6.1
Page 179, Photograph 6.2
Page 182, Photographs 6.5
Page 187, Photograph 6.6
Page 189, Photograph 6.7
Page 197, Figure 6.8
Page 206, Map 7.1
Page 210, Map 7.2
Page 211, Map 7.3
Page 213, Photograph 7.1
Page 214, Figure 7.1
Page 224, Photograph 7.13
Page 229, Figure 7.14
Page 245 , Figure 7.2

Glossary

DP	Direct Perspective
ICC	Implementation, Capture and Conclusion criteria
fMRI	functional Magnetic Resonance Imagery
HF	High Fidelity
MO	Modus Operandi, procedure
MP	Meta Perspective
MMP	Meta Meta Perspective
NPP	Nuclear Power Plant
PjB	Pre Job Briefing
OCL	Operator in Charge of Lockout
O/C	Opening/Closing a piece of equipment (Open/Close: state of equipment)
RCE	Relevancy, Completeness and Efficiency criteria
ROS	Real Operating Situation
RQ	Research Question
PQT	Perceived Quality Theory
RIW	Replay Interview
RP	Reliability Practices
SEBE	Subjective Evidence Based Ethnography
SAT	Systemic Approach Training
SimS	Simulated Situation
SPEAC	Square of Perceived Action
TAM	Take A Minute
TWC	Three Way Communication

Symbols & units

Symbol	Quantity	Units
df	degree of freedom	None
F	Fisher function	None
M	mean value	depending on the measured quantity
N	number of a sample	None
r	correlation coefficient	None
R	determination coefficient	None
SD	standard deviation	depending on the measured quantity
p	significance	None
t	t de Student	None
α	Cronbach alpha	None
χ^2	KHI-2 coefficient	None

Chapter I - Introduction: Industrial Context

Chapter I describes the rationale of the research project from the industrial standpoint considering an occupational need in complex socio-technical systems: the occupational context, the training context and the social context are briefly described. The way they shape the draft of a research question is argued. From an industrial standpoint, the issue is thus to know: What should be transferred by simulation training within the overall professionalization strategy of complex socio-technical systems of high risk industries in the current social context?
This industrial question addresses the more general scientific research question: What makes operational professionals competent in (collaborative) work activities through simulation training?
This relates to a corollary question: How can we create and mobilize competencies?
This structures the following literature review (Chapter II).

I-1 The rise of simulation for professional training in high risk industries (occupational context)

High risk technical industries are usually elaborated from a simple technical idea for basic needs. For example, nuclear production consists in producing electric energy from nuclear energy. That is to say taking the simple concept of the fission of atoms, obtain heat then use it to transform liquid (usually water) into pressurized gas and use the energy to power a turbine turning. This turbine is coupled to an alternator which produces electricity. Unfortunately, the technical accomplishment of an apparently simple idea remains complex and leads to the elaboration of a complex technical system that may give rise to safety problems (Amalberti, 1996, 2001; Reason, 1990, 2008, 2016).
Men and women are required to help this complex technical system operate, within an organization which in itself is complex. The complex technical system therefore becomes a complex socio-technical system. The issues of safety and reliability thus remain crucial from a technical standpoint but also from organizational and human standpoints. Amalberti (1996) speaks of resident pathogenic agents within the socio-technical system "like a virus that would become active during any favourable context". De la Garza & Fadier (2007) warn us about socio-technical systems that weaken over time (see also Heimann, 2005). This may be induced, among other factors, by the ignorance of certain risks, exploitation and production constraints and a tolerance within the organization that accepts that certain limits are exceeded (this is the normalization of deviation suggested by Vaughan, 1996 and 2005).

The efficiency and the improvement of safety and reliability of such complex socio-technical systems are based in part on the professionalism of the workers. This is elaborated through professional training within a professionalization strategy for which high fidelity simulation training has become a central resource especially for operational professions: “Simulations are recognized as an efficient and effective way of teaching and learning complex dynamic systems. Efficiency is gained by reducing the time it takes to reach a specified level of learning, and effectiveness is gained by achieving better results in performing the tasks learned” (Parush et al., 2002: 320). High fidelity simulation may take on different forms. There may be part-task or full scale simulators depending on whether the simulator reproduces part or as much as possible of the working environment respectively on a one to one scale (see for example Nilsson et al., 2015; Green et al., 2016).

However, the notion of “full scale” may affect the figurative dimension and/or the operating dimension (as discussed further in section II-4-2). A “full scale simulator” is usually devoted to the simulator reproducing both figurative and operating dimensions (see Figure 1) but some high fidelity simulators may rely partly or fully on the real operating field regarding the figurative dimension. This is the case for example when the Operations team in a nuclear power plant is trained for a given scenario on a full scale simulator reproducing the control room for the pilots while field workers’ activities must be simulated in the real operating field ("in situ simulation"); at EDF SA[2], the company which owns and operates the French nuclear fleet, this is called "interactive simulation".

[redacted]

a b c

Figure 1: Full scale simulators a) at Air France for aircraft pilots, b) with Da Vinci System for surgeons, c) at EDF SA for nuclear reactor pilots.

As a final example, hybrid simulators combine "both images of the real world and virtual images. Several types exist. It can be implemented on a computer where the user works with real and virtual images which are superimposed together to suggest on the screen a simulated situation for training purposes" (Fauquet-Alekhine, 2011: 23) (Figure 2). Attempts at categorizing simulators have been made but the huge variety of possible types makes the task quite difficult (see for example Alinier (2007) for the medical field).

[redacted]

Figure 2: Hybrid simulator ULIS for surgeon training (Marescaux & Soler, 2016) combining virtual scenes inside a patient on the computer screen and real surgical tools with force feedback.

Many operational professions are implicated; Anesthetists (Gaba, 1992; Yee et al., 2005; Müller et al., 2009; Agarwal et al., 2010; Ostergaard et al., 2011; Reader, 2011), Surgeons (Forest et al., 2007; Lightdale & Weinstock, 2011; Soler & Marescaux, 2011), Aircraft pilots (Petiot & Labrucherie, 2011), Fighter pilots (Amalberti & Deblon, 1992), Nuclear reactor pilots (Giersch et al., 2001; Pastré, 2005; De la Garza & Le Bot, 2008; Rousseau, 2008; Yuzhakov, 2010), Robotic pilots (Volov et al., 2002), Merchant navy captains (Clostermann, 2010). All these professions are concerned by both the individual and collective dimensions of occupational activities: being interlinked within a complex socio-technical system implies that, for most work activities, subjects will necessarily collaborate with someone else sooner or later; for example: Anesthetists with nurses or surgeons, Surgeons with nurses or Anesthetists, Aircraft pilots with co-pilots and members of the cabin crew and Air Traffic Controllers, Fighters pilots with co-pilots and Air Traffic Controllers, Nuclear reactor pilots with co-pilots and field workers or maintenance workers, Robotic pilots and co-pilots, and lastly Merchant navy captains with any members of the ship's crew.

[2] EDF SA: French branch of Electricité de France.

Despite the importance of the collaborative dimension, the assessment of the contribution of high fidelity simulation for training operational professionals was initially based on technical aspects thus forsaking the social interaction of workers. Since Rasmussen's pioneering studies (Rasmussen, 1983), simulators have taken the social-technical aspect into account. This improvement seems to have contributed towards shaping the central role of simulator training today (Labrucherie, 2016).

Furthermore, beyond its use in training, simulation has become a means for occupational qualification assessment of operational professions. Evaluation on simulators is now demanded by national regulators for the certification of high risk industrial professions such as aircraft pilots (Strachan, 2000) or nuclear reactor pilots (Ryzhov et al., 2010). This is due on one hand to the fact that training facilities give better results regarding the compliance of actions or expected outcomes (Parush et al., 2002; Altinok et al., 2007 ; Clevin & Grantcharov, 2008 ; Lucas et al., 2008 ; Kim et al., 2009; Causse et al., 2010; McCallum et al., 2011), even when just used in warm-up conditions (Calatayud et al., 2010), and on the other hand, due to progress in information technological as pointed out by Rosen (2008) for the medical field: "Innovations in flight simulation, resuscitation, technology, and plastics were essential antecedents to medical simulation. Computers facilitated the mathematical description of human physiology and pharmacology". Indeed, simulation has become a crucial tool for professionalization in high risk industries.

However, the next section shows that working on a simulator, which is central to training, can cause excessive focus on specific aspects of training.

I-2 Simulation training for rare situations (training context)

Simulation is now used as initial training and more and more as a means to train workers in challenging or rare accidental situations (Rogalski et al., 2002; Geeraerts & Trabold, 2016; Labrucherie, 2016). However, this sometimes results in forgetting the basic fundamentals of the profession: after the initial training period, trainees are mainly trained for these unusual situations. Everyday concerns may consequently be eliminated from the training sessions.

Current concerns may be those linked to the management of particular equipment during common activities. For example, when operating a nuclear reactor a common concern for the pilot may be to switch a pump of the primary circuit on or off. This implies knowing (or remembering) that switching on this sort of pump requires switching on the associated lifting pump first and then switching it off after about thirty seconds. Forgetting the latter detail may lead to an operating deviation called a "safety event"[3], this kind of deviation is better avoided in high risk socio-technical systems because of the possible deterioration of the equipment. The example described above caused a problem in 2013 at Chinon Nuclear Power Plant (France) despite the fact that the activity was familiar to the operators and was part of the procedure (Caillis, 2013).

Identifying that focusing training on rare situations may contribute, among other things, towards the occurrence of an event, it might be concluded that the pilot's professional training on a simulator in the framework of continuous training (or retraining) should include more of the fundamentals of the profession. Every year, safety events occur at French nuclear power plants due to this kind of situation, related to the basic content of the core of the profession.
They may also be more insidious such as those induced by the high level of requirements these sorts of industries demand thus leading to difficulties in applying overly complex procedures when compared to the basic information needed to perform the task: five lines to explain the core of the

[3] Deviations between realized and expected results in work activities on nuclear power plants are safety events assessed according to the International Nuclear Event Scale (INES). The scale counts 6 levels from 1 to 6. In France, EDF added the level 0 ("no importance from the point of view of safety") due to transparency concerns towards the national nuclear regulator. In practice, more than 95% of the safety events in EDF SA nuclear fleet are assessed at level 0.

task and how to perform it, two pages to warn the operator about potential problems, two more pages listing what is forbidden then four and a half pages describing the steps to be taken- rather than half a page of basic information regarding the action (see for example: Fauquet-Alekhine, 2015a: 5). This is the result of requirements and explicit or implicit regulations that constrain actions and interactions within the socio-technical system (Hasu & Engestrom, 2000; Béguin & Clot, 2004; Bruno & Monoz, 2012), combined with additional information resulting from feedback of the safety event analysis and pollution by operating details due to the belief that know-how and skills can be put on paper. The resulting procedure may be four times more what is strictly necessary to understand how to carry out the task, and lead workers to blindly apply the procedure rather than trying to understand the application of the procedures or making intelligent use of the tools that are at their disposition (Butterworth, 2010). Dubar & Mercier (2002: 182), when presenting an analysis of experienced workers' competencies at the French nuclear operator EDF, complained: "we write everything, we have to write everything and of course we must write competencies." A more recent analysis carried out at Chinon Power Plant (Fauquet-Alekhine & Boucherand, 2011: 36) aiming at identifying organizational resource and difficulties suggested that professional training had to be restructured: "rethinking the integration of know-how in professional training is necessary, and prior rethinking of access to this know-how is necessary: the 'all-in-procedure' is not a solution."

If workers are not trained to deal with such difficulties during the training period then the associated know-how can be developed through mentoring[4], a period during which knowledge, know-how and operating skills are expected to improve or at least develop. But is it possible? Does it happen? A survey regarding newcomers conducted in July 2013 at Chinon Nuclear Power Plant (Boucherand, 2013) gave eloquent data: among 135 participants (95.6% of operational jobs), 51% claimed to have no mentoring and 16% no tutoring so as to improve. These findings may be explained by taking an emerging social factor of the past decade into account: the skills drain.

I-3 Staff renewal and skills drain (social context)

West Europe industries, among which technological high risk industries, must now come to terms with the problem of the skills drain (Fitzpatrick, 2011; Manner, 2012; Richardson, 2012; Newcombe, 2013; Le Bellu, 2016) due to retirement. This reduces the contribution of experienced workers for tutorial and periods of mentoring. This social phenomenon is combined with an established depletion of professionalization in a work context with drastic requirements that makes the tools shaped and sized by operational and safety standards (Hasu & Engestrom, 2000; Béguin & Clot, 2004; Bruno & Monoz, 2012). The combination results in increasing difficulties for workers to fully apply procedures or use tools efficiently. The skills drain (not to be confused with "brain drain") may have a consequence on industrial safety (Murphy et al., 2010; Turner, 2013).

These findings point out the principal difficulties encountered by high risk industries (skills drain, reduced contribution of experienced workers as a tutor and for mentoring, depletion of professionalization, tools shaped and sized by operational and safety standards and regulations, difficulties for workers to perform a comprehensive application of the procedures or a clever use of tools), both in the field of operating and in the field of training. Coping with these difficulties, or at least adapting them, could bring great benefits for the companies in terms of performance and for the employees' well-being and health at work (for example, see Clot, 2008).

However, this is not so easy. The overall problem comes from opposite considerations:

- Companies face a skills drain which impacts "normal" operations BUT high fidelity simulators are mainly used for rare situation training.
- The contribution of experienced workers is fundamental to the newcomers mentoring periods BUT most of the experienced workers have retired or are about to be retired. If this is not the

[4] "mentoring" is the English translation for "compagnonnage" in French.

case, their involvement in high stakes work activities and on-call activities makes them unavailable for the training of newcomers.

From an industrial standpoint and in order to help newcomers elaborate competencies, the issue is thus to establish the following:
What should be transferred by simulation training within the overall professionalization strategy of complex socio-technical systems in high risk industries in the current social context?

The managers address this issue both from an individual and from a collective perspective as most high risk industrial activities are collaborative. Moreover, they form the hypothesis that if workers engaged in an activity are supposed to be collaborative without perceiving themselves as collaborating then their performance is reduced as they probably do not use collaboration to its full potential.

The industrial question addresses **the following more general scientific research question**:
What makes operational professionals competent in (collaborative) work activities through simulation training?
This relates to a correlate question: How can we create and mobilize competencies?

Firstly, these questions imply defining what we are referring to when we use "competent", "competencies" and what their links with knowledge, know-how and skills are. This is analysed in the literature review section II-1-1.

Secondly, these questions entail the need to better understand the way in which competencies may successfully be summoned and used to achieve an individual or collective activity in operating situations at work and how, when summoned in situation, they may be characterized for further training purposes. This is analysed in the literature review section II-1-2.

Thirdly, when defined and characterized, the issue is to apply the resulting material and conclusions efficiently in the framework of a professionalization process within a complex socio-technical system. This is analysed in the literature review sections II-3 and II-4.

Chapter II - Literature review & Research Questions

From the general scientific research question asked in Chapter I "What makes operational professionals competent in (collaborative) work activities through simulation training?" and its corollary question "How can we create and mobilize competencies? ", the literature review (Chapter II) is structured in four parts: "Defining competencies of experienced workers", "Models for competencies in action", "Methods to access competencies in action" and "Elaborating and applying competencies in high risk industries".

"Defining competencies" examines how the literature makes the link between knowledge, know-how, skills and competencies. It suggests that competencies must be mobilized in order to perform an activity and that this mobilization is multi-factorial and occurs when in action. It results in: (RQ1) How are competencies of experienced workers mobilized and how to access them? It also advocates for a framework based on Activity Theory.

"Models for competencies in action" examines theories and key concepts regarding activity and its collaborative dimension, emphasizes the importance of the concept of "competencies in action" and reviews the available models and methods which might depict this concept. This results in selecting Le Boterf's model for test and potential application.

"Methods to access competencies in action" explores the Cognitive Task Analysis paradigm so as to select a method for accessing competencies in action. This orients us towards "process tracing" method based on first-person video recordings of activities followed by replay subjective interviews.

"Elaborating and applying competencies in high risk industries" questions the professionalization system within complex socio-technical systems in high risk industries, thus including simulation training; it also explores how the professionalization system may be modeled. This leads to (RQ2): How are 'mobilizable competencies' elaborated through training in high risk industries? In addition, it attempts to clarify the collaborative dimension of work activities with a particular focus on its intersubjective aspect.

II-1 Defining competencies of experienced workers

Here the question of defining knowledge, know-how, skills and competencies is addressed. It is common to hear trainers or trainees, workers or managers use these words indifferently. It is even difficult to form a clear idea about these concepts when reading the scientific literature as shown hereinafter.

II-1-1 Competencies – Definition

A team at the European Center for the Development of Vocational Training (Luxemburg), Winterton and co-workers (2006), published a report giving a detailed description of what- according to their analysis- knowledge, skill and competence are, although their bibliographic review has put the contribution of ex-Soviet researchers to one side in favour of West-European and Anglo-Saxon researchers. The same shortfall arises in the review of Boucher et al. (2007).

These reviews suggest that the literature distinguishes two kinds of learning processes: i) single-loop learning related to knowledge based on existing premises so as to solve specific problems (Dodgson, 1993), ii) double-loop learning which aims to establish new premises such as mental models and perspectives (Argyris and Schön, 1974; 1978; Bateson, 1973). Knowledge development is part of a learning process (Nonaka & Takeushi, 1995) which may concern a cognitive dimension (understanding and the use of new concepts) and/or a behavioural dimension (the physical ability to act) (Garvin, 1993), the interaction of which within a social system leads to organizational learning (Senge, 1990).

Knowledge includes both declarative knowledge (explicit, factual knowledge) including theory and concepts, and tacit knowledge resulting mainly from experience (Polanyi, 1958, 1967; Wagner & Sternberg, 1986; Eraut, 2000; Polanyi & Sen, 2009) which is sometimes difficult to put into words, such as using a ruler to measure the axis of a pump. Furthermore, the work of Wenger (1998) showed that information at work is context-sensitive and only makes sense if it is maintained by a community of practice, a group of people involved in a common concern giving rise to shared actions on a regular

basis. According to Wenger, communities of practice are a necessary condition for the sustainability of tacit knowledge.
Regarding skills, Winterton and co-workers quote Proctor and Dutta (1995). According to them "the most authoritative text on skill acquisition and performance", who define skill as "goal-directed, well-organised behaviour that is acquired through practice and performed with economy of effort", distinguishing perceptual skills, response selection skills, motor skills and problem-solving skills. Before them, Rasmussen (1983) suggested skill-based behaviour as "highly integrated patterns of behaviour", related to "sensory-motor performance during acts" following intention and happening without conscious control.
Defining "competence", however, is less easy. According to Winterton and co-workers, "there is such confusion and debate about the concept of competence that it is impossible to identify or impute a coherent theory or to arrive at a definition capable of accommodating and reconciling all the different ways the term is used". Moreover, some authors use "competency" instead of "competence" to name occupational competence (Boam & Sparrow, 1992; Hendry et al., 1995). For Winterton and co-workers, "competency captures skills and dispositions beyond cognitive ability such as self-awareness, self-regulation and social skills". Winterton and co-workers conclude that, "if intellectual capabilities are needed to develop knowledge and operationalizing knowledge is part of developing skills, all are prerequisites to developing competence, together with other social and attitudinal aspects." The statement they retain as being the clearest is from Woodruffe (1991) who defines "occupational competence" as "aspects of the job which an individual can perform, with competency referring to a person's behavior and underpinning competent performance" where the competence-performance approach has been conceptualized in the line of Chomski's work (1980) in linguistics.

More recently, Peregrin (2014) reminded us of guidelines provided by the American Northwestern University (2004): competencies may be seen as describing skills, knowledge and behaviour necessary to perform the job. In this case, skills would be abilities needed to execute job duties, such as software and computer proficiency, accounting skills or specific laboratory techniques (occupational competencies), and also interpersonal skills (generic competencies) (see also Heijke & Meng, 2004). Knowledge would be linked with areas of specialty or expertise; for example, nursing, finance, employment law, or history. Behaviour would be linked with characteristics an employee must display in the job; for instance, initiative, collegiality, resourcefulness or professionalism.

From the ex-Soviet researchers' standpoint, know-how refers to the knowledge of knowing how to do something and that knowledge may be considered as the combination of acquired data and acquired rules connected by the ability to manage them together (Ilyenkov, 2007) or, in other words, supported by the intellect (Leontiev & Luria; 1937/2005; Sokolova, 2002). Leontiev & Luria (1937/2005) suggest that skills are cognitive processes. These cognitive processes provide the link between acquired knowledge and what will later become competencies; acquired knowledge must first be transformed into know-how. Ilyenkov (2007) emphasizes this point as follows: "there must be a special ability that is distinct from knowledge itself, the ability to 'apply' the knowledge in one's possession." Considering this finding, Ilyenkov points out the necessary existence of a mediator between knowledge and competence, the "ability to apply" which he calls a "special skill": "the question arises: can this special skill be learned and taught?" Based on the "Critique of Pure Reason" by Kant, Ilyenkov demonstrated that this skill is an "innate ability". Before Ilyenkov, Talyzina (1984) highlighted how actions were necessary to achieve the learning process: "Actions thus are one of the components that determine the effectiveness of any learning process." We may extend her proposal to the previous considerations and suggest that actions contribute towards elaborating know-how from knowledge.
Therefore, competencies coming through actions can only be achieved during an activity situation, determined by intentions, goals and context according to the Activity Theory (Leontiev, 1974; Nardi, 1995). Furthermore, competencies originating from knowledge, knowledge being specific and needing specific skills to rise in competencies, competencies are necessarily themselves specialized.

The French speaking movement of ergonomics and psycho-sociology complement these findings with a lexical difficulty induced by the fact that "skills" and "competencies" are translated by the same French word "*compétences*". Montmollin (1986: p122) suggested a description of skills or competencies as "stabilized sets of knowledge and know-how, of typical behaviours, of standard procedures, of types of reasoning, that one can implement without new training. Competencies [skills] stabilize and structure the achievements of professional history; they allow the anticipation of phenomena, of implicit within requirements, of variability in the task". For Samurçay (2005), a novice's anticipation is local, short loop while experienced workers have an overall anticipation of the system and are able to manage interactions between different phenomena. This means that novices have a superficial knowledge while experienced workers have a deeper understanding of the work situation. Leplat (2001) noticed that skills or competencies are unobservable by nature: only their manifestations may be observed.

In addition, some knowledge mobilized in work activity is experience-based or "experiential" (learning is achieved through own experience and involvement), in most cases internalized as tacit knowledge (Polanyi, 1967). They have progressively become unconscious and may become automatisms (Nonaka & Takeuchi, 1995). The more experienced the worker and more it becomes difficult to obtain the description of some actions of the work activity. The model developed by Nonaka (1991) distinguishes four knowledge conversion processes: Socialization, Externalization, Combination, and Internalization. It is the SECI model (Figure 3). "Socialization" allows the passage of tacit to explicit to promote transmission from the experienced worker to the novice. "Socialization" enables the sharing of experience and mental models; it is the case through mentoring. Yet as we explained, the process tends to diminish then disappear. "Externalization" is mostly verbal or written; this process is difficult to implement because tacit knowledge is necessarily difficult to verbalize. "Combination" is to combine discrete parts of explicit knowledge into a new whole. "Internalization" happens when new explicit knowledge is shared between workers through organization making some of them reframe their own tacit knowledge.

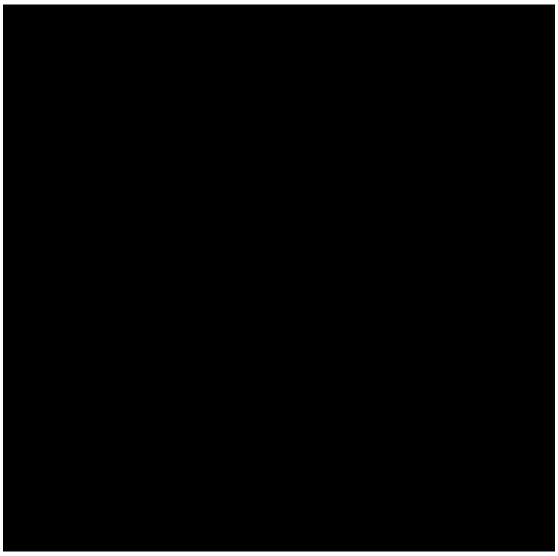


Figure 3: The Spiral of Knowledge' or the SECI Model.

As can be seen, if all different scientific currents mention knowledge, know-how, skills and competencies and identify a link between them, the relationships remain slightly different from one to another and this diversity does not simplify the problem. Table 1 summarizes the results obtained through the literature review.

Therefore, an attempt to summarize and conciliate the considerations exposed in the literature review is needed. It cannot claim to be the truth but at least the most adapted choice to understanding the present issue. It gave the following.

Skills are consecutive to knowledge and know-how: knowledge is a prerequisite to skills since, before developing skills in a field, one must learn from oneself through heuristics or from others through lessons, imitation, training and son on. Know-how is also a prerequisite to skills in that it constitutes a lower level in terms of performance, of having the skills, to perform a task. Know-how and skills develop through action: this refers to the ability to apply knowledge involving one or more cognitive process. Action is resolutely necessary to transform knowledge into know-how which then becomes skill. These skills are also developed through action in situation: they are specialized. The action is therefore required to achieve the learning process if the outcome is the elaboration of know-how and skills.

Table 1: Definitions of knowledge, know-how, skills and competencies

knowledge	know-how	skills	competencies
●may concern a cognitive dimension and/or a behavioural dimension (Garvin, 1993) ●within a social system may have an organizational dimension (Senge, 1990). ●includes both declarative and tacit aspects resulting mainly from the experience (Polanyi, 1958, 1967; Wagner & Sternberg, 1986; Eraut, 2000; Polanyi & Sen, 2009) ●communities of practice are a necessary condition for tacit knowledge sustainability (Wenger, 1998) ●is prerequisites to developing competence (Winterton et al., 2006) ●combines acquired data and acquired rules linked by the ability to manage them together (Ilyenkov, 2007) ●is supported by the intellect (Leontiev & Luria; 1937/2005; Sokolova, 2002) ●is superficial for novices (Samurçay, 2005) ●may be tacit or explicit (Polanyi, 1967) ●socialization allows the passage of tacit to explicit (Nonaka, 1991)	●refers to the knowledge of how to do (Ilyenkov, 2007) ●is transformed from knowledge (Leontiev & Luria; 1937/2005) ●is elaborated from the knowledge through actions Talyzina (1984)	●are goal-directed, well-organized behaviours that are acquired through practice and performed with economy of effort (Proctor & Dutta, 1995) ●have several dimensions: perceptual skills, response selection skills, motor skills and problem-solving skills (Proctor & Dutta, 1995) ●are highly integrated patterns of behaviour during acts following intention without conscious control (Rasmussen, 1983) ●occupational competencies: abilities needed to execute job duties (Peregrin, 2014) ●generic competencies: interpersonal skills (Heijke & Meng, 2004; Peregrin, 2014) ●are cognitive processes making link between the acquired knowledge and what will later become the competencies (Leontiev & Luria; 1937/2005) ●includes an innate ability to 'apply' the knowledge (Ilyenkov, 2007) ●are unobservable by nature (Leplat, 2001)	●capture skills and dispositions beyond cognitive ability such as self-awareness, self-regulation and social skills (Winterton et al., 2006) ●aspects of the job which an individual can perform, with competency referring to a person's behaviour and underpinning competent performance (Woodruffe, 1991) ●are the skills, knowledge and behaviour necessary to perform the job (Peregrin, 2014) ●are stabilized sets of knowledge and know-how, of typical behaviours, of standard procedures, of types of reasoning, that one can implement without new training (Montmollin, 1986) ●are unobservable by nature (Leplat, 2001)

There is thus a bilateral relationship which makes it impossible to dissociate action and skills: within the learning or working situation, competencies exist through action, and action in situation must necessarily produce competencies. This means that knowledge gives know-how through action and that know-how becomes skill through experience, that is the repetition of the subject's exposure in situations of action whilst having to apply knowledge and know-how. The repetition of the subject's exposure in a situation implies variability: experience develops through the variability of situations encountered (Montmollin, 1986; Rogalski & Leplat, 2011) since activities associated with a given task are always different due to changes in context, to different interactions with co-workers, to unplanned disturbances (Norros, 2004).

Analysis of work activities already carried out in numerous situations in aircraft, medical and nuclear industries (Fauquet-Alekhine & Labrucherie, 2008, 2012; Fauquet-Alekhine et al., 2011a, 2015a; Fauquet-Alekhine & Boucherand, 2012; Fauquet-Alekhine, 2011, 2012b, c, d, 2013a, 2014b) showed that we may adopt a proposal that matches most of the considerations developed in the theoretical review above. It would be fastidious and without interest to give an example for each of the points in the table and for each industry to demonstrate this; however, from a general standpoint, the aircraft pilots, the anaesthetists or the surgeons, the nuclear reactor pilots or their technician co-workers, all have shown acquiring new knowledge before developing new know-how.

The approach is thus to consider competencies as an overall concept designating knowledge, know-how and skills where knowledge is a prerequisite to know-how and skills. Skills develop from know-how in action with experience, where "experience" means being exposed to situations several times and at a certain frequency (it is quite different to perform a task once every ten years or ten times in one year). Having skills is therefore possessing know-how that has been put into action several times (in the event of the situation). Thus, identifying know-how and skills on paper may be difficult. Figure 4 summarizes the proposal in a concise schema highlighting the logical relationship between knowledge, know-how and skill, the whole being competencies. Competencies gain in efficiency when the subjects' number of exposures (Y-axis) to the situation increases and when its rate (X-axis) increases too. It also provides clear identification of the kinetics of loss of competencies (when the rate decreases) and conversely the kinetics of recovery of competencies. The triangular zone noted as an "inaccessible zone" is an arbitrary area postulated inaccessible as at least two exposures to a situation are needed to calculate a rate of exposure.

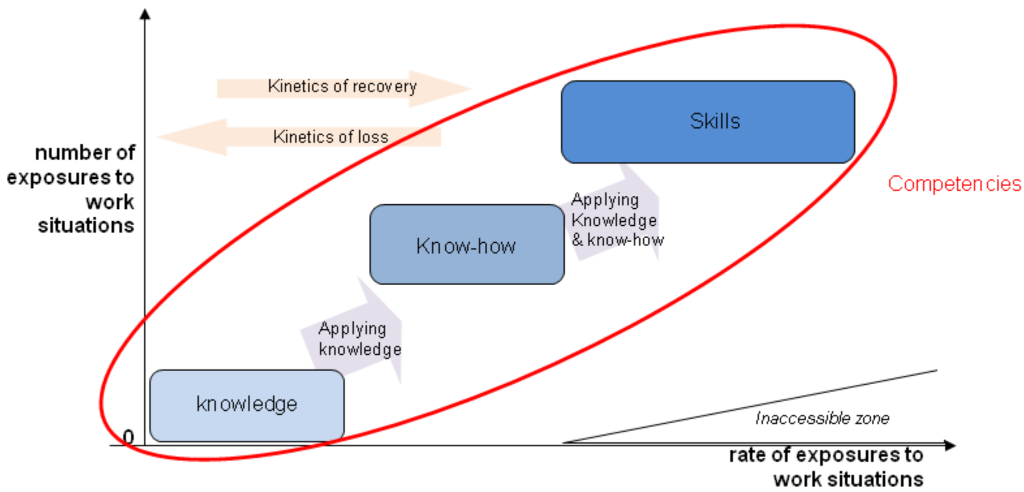


Figure 4: The nesting concept of competencies based on knowledge, know-how and skills: the KKHS synthesis.

For the sake of accuracy below, we shall designate representation in Figure 4 as the KKHS synthesis (Knowledge, Know-How and Skills synthesis).

II-1-2 Competencies and experienced workers

Considering competencies in activities suggests reviewing the Activity Theory from the outset which provides key-concepts to understand the point better.

Activity Theory

Several currents of Activity Theory are available in scientific literature which vary depending on the disciplinary standpoint adopted by the authors.

Activity Theory originates from 1920s Soviet psychology and began to be broadcast internationally from the 1970s.

Activity Theory then developed in the Soviet Union (Rubinstein, 1922, 1946; Lomov, 1963; Leontiev, 1975), and appeared as one of the essential sources of renewal and development of psychology and ergonomics. Increases in the number of Action Theory publications in Western Europe and Anglo-Saxon countries are proof of this: the number of translations of Russian authors increased, works of syntheses appeared (Engeström, 1990; Bødker, 1991, 1996; Cole, 1996; Kaptelinin, 1996; Bedny & Meister, 1997; Rabardel & Pastré, 2005; Nosulenko & Rabardel, 2007). In 1962 the *International Journal of Psychology* was created in the USA, publishing the translated and original materials of

predominant authors from countries of the former Soviet Union and Eastern Europe. The journal went under the names of *Soviet Psychology and Psychiatry* (1962-1966) and *Soviet Psychology* (1966-1991), and since January 1992 has gone under the name of the *Journal of Russian & East European Psychology* (6 issues per year).
Theories of activity provide methodological tools that facilitate the analysis of occupational activities in technological contexts. According to Barabanshikov (2007), the synthesis of the approaches of Russian psychology reveals a series of important properties of activity: there is no activity without subject and object, the activity is conscious, and it is social in nature.

Rubinstein, precursor of the theory, considered that studies in psychology should focus on the subject. He had therefore developed an anthropocentric approach towards activity: subject-oriented activity (Rubinstein, 1922).
The strength of his theory lays in the fact that it permitted circumvention of the methodological opposition between 'objective' and 'subjective': consciousness, perceptions are subjective constructs that are an objective reality for the subject. The subjective exists objectively. It is thus observable and assessable either by objective measurements of the physiological state, or through the description that the subjects produce themselves about their internal states (thoughts, emotions, feelings).
Around 1920, Rubinstein worked on the traditional opposition between consciousness and activity. His reflections on the question led to the unification of these two concepts by a new methodological principle, consciousness that manifests and develops itself in the activity: activity and consciousness are two potential intermediates of the interaction between the subject and the object of the subject's activity (the motive). This brought Rubinstein to the concept of subject-oriented activity.

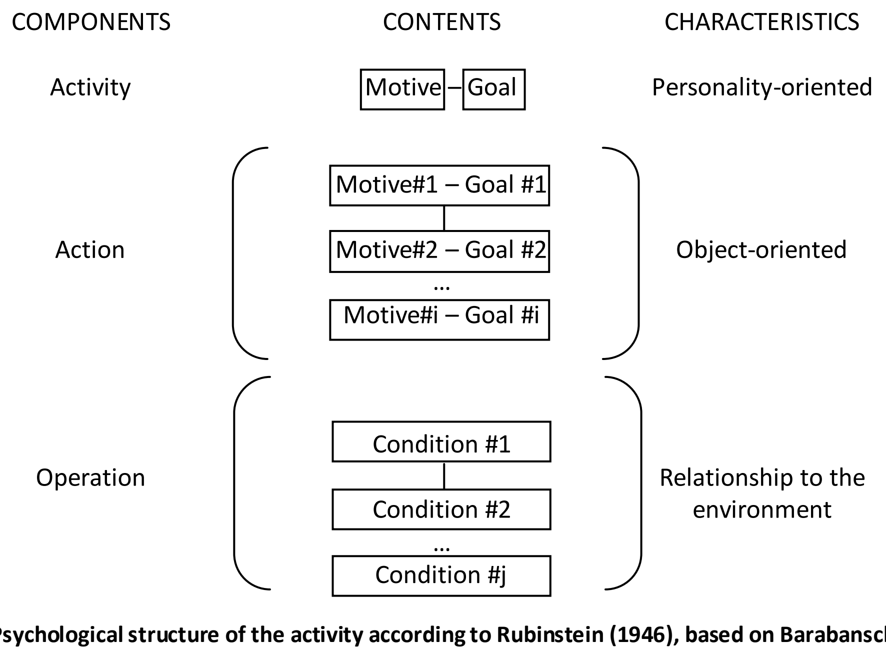


Figure 5: Psychological structure of the activity according to Rubinstein (1946), based on Barabanschikov (2007).

Rubinstein then extended his work by considering the personality in the activity, associated with the concepts of consciousness, needs and capabilities. The unit consciousness-activity therefore implied considering the personality-activity unit (Aboulkhanova, 2007). The subject achieves lifelong unity of personality and of consciousness.
Rubinstein's work led to a dynamic model of the personality-activity system (see Figure 5). The dynamic character of the structure is particularly linked to the mobile nature of the link between motive and goal: for example, the goal may detach and attach to a result, thus generating new goals

Lomov developed a relationship with the Activity Theory which is similar to that of Rubinstein. Lomov considered that human cognition could not be studied independently of communication processes. This consideration led him to think of human communication and activity as two distinctive but interdependent characteristics of the subject.
He built a methodological approach of a systemic nature in psychology whereby a given object of study should be considered from various angles. In his book "Man and Technology" (Lomov, 1963), he advocated the need to take the human factor into account when designing tools and work systems. He thus suggested the bases of the psychology of engineering and contributed towards the foundations of the ergonomics of systems.

Leontiev, student of Vygotsky, developed a vision which was both bounded and exclusive of Psychology, in that everything must be studied through activity and its structure. Despite the fact that, according to him, the Activity Theory was the only valid theory available to study human functioning, he focused only on individual activity.
For Leontiev, the structure of the activity is determined by the object of activity, i.e. the motive (Figure 6).

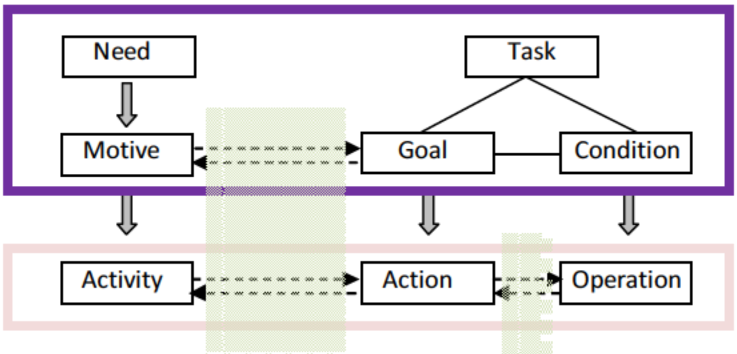


Figure 6: Psychological structure of the activity according to Leontiev (1965), based on Barabanschikov (2007): external dimension (pink frame), internal dimension (purple frame), relationship dimension (green area).

From a psychological standpoint, there are three dimensions of activity among which two are correlated. One is the observable external dimension (pink frame on Figure 6) with the existence of structural units: activity, actions, and operations. These units are the psychic reflection of the subject. The second dimension (purple frame on Figure 6) is internal: it is the subordination of these structural units to the content of the object of activity: needs, motives, general and specific goals. Interaction of the subject with the object is an activity with regards to the motive and a set of actions with regards to the goal.
In Leontiev's theory, the object of activity matches the motive of activity. This motive is an objectified need, from a need perceived as a lack. The motive carries stimulation, since it satisfies a need. It is also the motor of activity: the motive boosts and guides the activity. The nature of this motive may vary and determines the form of the activity: a physical need leads to a producing something tangible (physical object), a cognitive need leads to intellectual production (for example: production of rules), a functional need (for example: maintaining one's physical condition) leads to functional activity (for example: a sports activity). The goal is the conscious mental representation of the expected result. The goal is to the action what the motive is to the activity. It represents the object that guides the action. Tasks are associated with specific goals in context. Performing the activity is conditioned by the logic of the progress of the goals or tasks performance and is accomplished through actions subordinated to conscious goals. Operations correspond to the means of implementation of actions and are directly determined by the tasks. These components of activity cannot be isolated from each other. They constitute a system whose relationships enable transformations or shifts of components. The third relational dimension of activity (green area and dotted lines in the Figure 6) reflects the dynamic nature of activity. This flow of mutual transformations makes activity become action and conversely

the action may become an activity; the motive can become a goal and vice versa. Similarly, when the action is more conscious, it becomes an operation and the operation may become action whenever a problem occurs and interrupts the automatic process implemented.

Nowadays, Activity Theory has been revisited and is adapted to uses in various fields: design, work analysis in the field of education. Many authors of Western Europe and Anglo-Saxon countries have proposed their own interpretation and use it as a theoretical framework (Daniellou & Rabardel, 2005; Rogers, 2008).

The goal-directed action theory (Von Cranach & Kalbermatten, 1982; Von Cranach, Mächler & Steiner, 1985) is an example. It provides precise vocabulary describing mental processes related to the activity. It is based on an interview with self-confrontation, and is extremely useful to understand better the cognitive mechanisms: the subjects individually watch video recordings of their own practices and are invited to share their cognitive processes during the replay action.

Communities have developed around this framework. This is particularly the case in the field of the "Human - Computer Interaction", which Suzanne Bödker who initiated the movement in the late 1980s (Bannon & Bødker, 1991; Bødker, 1989, 1991; Kuutti, 1991, 1996; Kaptelinin, Kuutti, & Bannon, 1995; Kaptelinin, 1996; Nardi, 1996). This community of researchers showed how Activity Theory provides a framework for effective analysis to study the interactions between humans and artifacts that they manipulate, in their historical and cultural context.

Another community was born around Engeström (Engeström, 1990; Engeström & Middleton, 1996; Engeström et al., 1999) regarded as one of West European specialists in the development of Activity Theory in the field of education science. Engeström suggested an enriched structure of the activity defined by Leontiev by adding the concepts of rule, community, and division of labour. His first attempt modelled activity on Vygotsky's concept of mediation bringing together human actions and cultural artifacts but this model presented the drawback to focus on the subject. He thus suggested that mediation should be considered on its relationship with other components of an activity system as artifacts had to be seen "as integral and inseparable components of human functioning" (Engeström et al., 1999: 29). The activity was considered at a macro level: introducing the community, he integrated social collective elements in the activity system organized through rules and implying division of labour, all of them interacting through relationships schematized in its model by two nested triangle (Figure 7): "Within the community, the members continuously negotiate their division of labour, including the distribution of rewards. The temporal rhythms of work, the uses of resources, and the codes of conduct are also continuously constructed and contested in the form of explicit and implicit rules" (Engestrom, 2006: 4). The system was seen as producing object-oriented actions characterized by sense, the outcome being elaborated through multiple transformations from the original idea to the finished and stabilized object.

Figure 7: Engestrom's activity system
Source: Engestrom, 2006; Engestrom et al., 2010 quoting Engestrom, 1987: 78

Joint activities could therefore be easily modelled on by two activity systems interconnected through a shared object defined as a "potential common ground or synergy between the two [system] perspectives" (Engestrom, 2006: 4). Within such a network of activity, Engestrom emphasized the importance of contradictions and constrains in the definition of the motives and the object of the activity. According to Engestrom et al. (1999), activity had to be considered as a system within its network relations to other activity systems (underlining the importance of the relationship of the activity to other activities), each of them taken as the prime unit of analysis.

In France, the work of Ombredane & Faverge (1955) can be considered as a parallel current to the Soviet developments of the time. They proposed a conceptual framework similar to that provided by the Russian theories of activity. Other French researchers used the Activity Theory as a conceptual framework (Rogalski & Samurçay, 1993; Rabardel, 1995; Vergnaud, Samoylenko, & Galkina, 1997; Clot, 1999, 2000; Rabardel & Pastré, 2005).

Despite the aforementioned contribution of Engeström, some authors still estimated recently that the weak point of Activity Theory lays in that it does not take into account the role of the tool in the structure of the activity. Le Bellu (2011) noted that "for more than ten years, the Franco-Russian team Lahlou, Nosulenko and Samoylenko have been trying to fill the gaps pointed out by Davydov in implementing the principles of the theory of activity through the paradigm of 'perceived quality' by using digital ethnography" (Nosulenko, 2008; Lahlou, et al., 2011). This is presented in the next paragraph.

Perceived Quality Theory (PQT)

The Perceived Quality Theory (PQT) synthesizes and combines elements of the Activity Theory (Leontiev, 1975; Rubinstein, 1922, 1946) and the theory of mental image (Lomov, 1984), for application to the analysis of situations of daily or occupational life. It is a theoretical basis for studying activities in their relationship to objects that are relevant to the subjects in the determination of their intentions. In this perspective, the definition of Perceived Quality may be formulated as follows: "a set of subjectively relevant characteristics of the world and the activity elaborated by subjects in order to achieve their goals" (Nosulenko, 2008: 400). This approach offers a psychological perspective that seeks to understand what is perceived (perceived quality) by the subject on completion of an activity such as a professional technical gesture. To do so, it suggests an overthrow of the psychophysical traditional paradigm creating a stimulus to study the responses associated with it. Conversely to the Activity Theory, the notion of tool is important in the PQT, even central, since the perception of the tool by the subject is the filter through which the activity is analysed.

The aim here is to understand what the most relevant components of the situation are or of the artifact (that is their perceived quality) that subjects perceive as elements organizing their activity. The method is first to identify clearly the components of the perceived quality to infer later the characteristics of the situation or of the artifact that determine these components by matching these components of the perceived quality (in Le Bellu's study, the oral explanations given by the subject of the gesture) with the observed components of events (professional gesture performed by the subject). A set of techniques developed under this paradigm provides mapping of observational data (e.g. video recordings, measures of technical parameters, analysis of the requirements, procedures) and data characterizing the subjective experience of the subject (interviews, dialogue regarding the objects and components of the perceived activity). For Le Bellu (2011) or Lahlou et al. (2011), this was undertaken through the replay interview[5] and further analysis.

These developments come back to competencies in action with an important role of the goal, the means (including tools) and the collective dimension, the latter echoing to Distributed Cognition.

[2] Here, replay Interview (RIW) should be understood as an interview based on the video of those performing the activity; "replay" underlines the fact that the subject watches the past activity on the video.

Distributed Cognition

Facing the analysis of collaborative activities in the present study, the Distributed Cognition approach is essential. In this approach, the unit of analysis is a cognitive system composed of individuals and artifacts they use (Flor & Hutchins, 1991; Heath & Luff, 1991; Rogers & Ellis, 1994). This approach provides a framework for a detailed analysis of the artifacts, provides widely applicable design axes, and studies the interactions between humans and the system and the interaction human-human, i.e. the phenomenon of coordination or collaboration.

The strength of this approach lies in its interest in the phenomena of coordination / cooperation which operate within the groups.

Derived from Cybernetics theories (Wiener, 1948; Ashby, 1957) and from the general theory of systems (Bertalanffy, 1968), Distributed Cognition is an approach that focuses on the functioning of the system. It seeks not only to emphasize the internal representations of the subject but is also interested in the representations created and disseminated through the artifacts, to provide a detailed analysis of these (Norman, 1988, 1991 ; Zhang & Norman, 1994; Hutchins, 1995a; Nardi, 1996) to identify ultimately the broad principles of design that are widely applicable.

Numerous studies were conducted to examine the way several individuals coordinate whilst performing tasks on a system, and sharing a common goal of production or realization: ship navigation (Hutchins, 1995a), aircraft flight in cockpit (Hutchins, 1995b, Hutchins & Klausen, 1996), engineering practices (Rogers, 1993), computer specialists working in teams (Flor & Hutchins, 1991). These studies highlighted the crucial role of objects (cognitive artifacts, mediation structures) in the coordination and performance of the action.

Distributed Cognition (Rogers & Ellis, 1994; Hutchins & Klausen, 1998) considers the coordination techniques of subjects sharing a common goal within functional systems, i.e. individuals and artifacts and their relations to each other whilst performing a given task. As Situated Activity, Distributed Cognition points out the necessity of coordination for successful collaboration, and therefore the necessity of existing factors of coordination (e.g. interfaces, communications). As for Activity Theory, Distributed Cognition emphasizes the importance of the goal of the activity and highlights the necessity for this goal to be shared by co-workers in order to obtain collaboration: co-workers elaborate shared expectations giving rise to a shared goal. As pointed out by Zager (2002), this means that if interaction or collective objects (including activity goal) do not exist, collaboration does not occur. Yet Distributed Cognition suggests a broader scope of analysis for socio-technical systems: the central unit of analysis being the functional system, it analyses how the content of this system is physically distributed (over artifacts related to users), socially distributed (through representations among subjects) and temporally distributed with the propagation of knowledge and information through the system (dynamic aspect) (Kirsh, 2000). This distribution-based approach permits the mapping out of the shared knowledge and associated communication vectors at both individual and collective levels. It may show complementary and redundant knowledge between co-workers, mismatches between shared expectations, or knowledge propagation disruptions causing coordination disturbance and therefore limiting the possible performance for the collaborative activity.

It is clear at this point that competencies must be mobilized in order to perform an activity and that this mobilization is multi-factorial and occurs when in action. This leads to a research question:

RQ1: How are competencies of experienced workers mobilized and how to access them?

Initial elements to answer this question may be found through models of competencies in action.

Activity Theory vs Distributed Cognition

Halverson (2002) undertook a comparative analysis between Activity Theory (AT) and Distributed Cognition (DCog) applied in the field of Computer Supported Cooperative Work. Despite several common points (both include the social and cultural context of cognition, both share a commitment to ethnographically collected data), she pointed out that "Although a DCog analysis is centred on cognitive processing, AT keeps process explicitly in the foreground by diagramming relations between elements within the activity system" which is very useful to identify "various elements and their relationships to explain the workings of the system" (p.260). In addition, "AT's basic structure posits certain kinds of process interrelationships, which are implicit even when the analyst may not make them explicit. DCog obscures those relationships somewhat by focusing on the lower level" (p.261). Furthermore, several authors recommend AT for studying collaborative activity. According to Antoniadou (2011), many studies have highlighted how AT could help in understanding the complexity of collaborative activities towards the achievement of a shared object by means of various artifacts. More recently, Stuart (2014) showed how Activity Theory was an appropriate frame for professionals seeking to understand how to work collaboratively which was already suggested earlier by Bardram (1998): "Activity Theory seems to provide appropriate conceptualizations, suited for analysing cooperative work its dynamic transformation, and the importance of cooperative breakdowns" (p.91).

To summarize section II-1, it is suggested that knowledge gives know-how through action and that know-how becomes skill through experience; competencies regroup knowledge, know-how and skills in interactions. It is found that competencies must be mobilized in order to perform an activity and that this mobilization is multi-factorial and occurs when in action. It results in: (RQ1) How are competencies of experienced workers mobilized and how to access them? It also advocates for a framework based on Activity Theory.

II-2 Models for competencies in action

Seeking the literature in order to find a model linking competencies or skills and action inside the activity, one approach consists in looking for models of action, and another one for model of competencies. Surprisingly, very few models are available in the literature from both sides.

Regarding models of actions, the model of Searle (2001) is derived of the model of Davidson (1980), the latter being called the "classical model" by Searle. Briefly, both are based on the subject's desire and belief to draw and trigger the action with a rational dimension that is mainly a matter of rules in the classic model. Searle added the notions of rationality related to free will before action and adjustment during action. Free will explains the gap between the motivation desire and the decision making. Searle also emphasized the importance of a "motivator" for action which may be internal (a desire) or external (an obligation). While the models focus on the articulations between rationality, motives and action, none of them consider competencies related to action.

Gollwitzer suggested a model of "action phases" with four different consecutive action phases of goal pursuit: the predecisional phase for deliberation regarding desirability and feasibility of goals, the preactional phase to determine means and time to act towards the chosen goal, the actional phase implying a series of goal-directed behaviour towards achieving the goal, and the postactional phase for assessment of the achieved outcomes (Gollwitzer, 1990; Heckhausen, 1991; Faude-Koivisto et al., 2009). The model was later refined and led to the mindset theory of action phases (see for example Gollwitzer, 2012) suggesting that when involved in the consecutive phases, some ways of thinking become prominent. The deliberative mindset relates to decision making in the predecisional phase and the implemental mindset in the preactional phase relates to planning the steps to reach the goal. The model suggests a comprehensive temporal perspective on the course of action and does not make link with competencies; it mainly deals with goal intention and implementation intention.

The models of situated action (Suchman, 1987; Suchman and Trigg, 1991, 1993; Fornel & Quéré, 1999) present action as responses to the environment and related goals as retrofitting constructions of the subject compared to the activity carried out. In this context, the subject does not develop the goals of the action. The action itself is therefore a reaction to the situation experienced rather than an action in a situation. A first issue emerges here: action as reaction posits motives and goals at a secondary level when compared with the situation and suggests that there is no pre-existing knowledge to action as action develops only in situation. Moreover, these approaches focus on the situation and on the activity in a situation without paying enough attention to the subjects and their interpersonal relations, the artifacts and their interactions with subjects. These models can hardly fit the theoretical framework chosen for the present work, the Activity Theory (Leontiev, 1974; Nardi, 1995) within which we consider competencies coming through actions and being achieved within an activity situation, determined by intentions, goals and context.

The TOTE model suggested by Miller et al. (1960) was innovative in that the authors were first modelling the contribution of mediating vectors between stimulus and response in action. They described action as successive steps and feedback within a progressive structure: Test – Operate – Test – Exit. However, the action is restricted to a simple and limitative cognitive process which does not relate to competencies and remains far from the notion of activity.

The model of planned action (Fishbein & Ajzen, 1975; Ajzen, 1985) introducing the cognitive intentional dimension of action, models the relationships between beliefs, attitudes, behavioural intentions and behaviour: behavioural intentions and behaviour are shaped by subjective norms, perceived behavioural control and attitudes towards the behaviour itself. Like the TOTE model, the model of planned action is mainly cognitive processing-based as a linear decision-making process: it does sufficiently account for factors influencing intention and motivation such as emotion and past experience and, focusing on beliefs and attitudes, competencies needed to achieve the goals are not modelled.

Regarding general models of skills or competencies(as opposed to specific skills or competencies models dealing for example with reading or leadership), the well-known Dreyfus's skills model (Dreyfus & Dreyfus, 1980) is limited to a suggestion of different steps characterizing the subject's levels of competencies; the model slightly changed after the original version and Eraut (1994) suggested: novice (rigid compliance with rules mainly), advanced beginner (actions based on attribute or aspects), competent (have developed know-how with experience), proficient (develop their own rules and their repertoire of experienced situations), expert/master (choose intuitively the appropriate action from their repertoire of experienced situations, characterized by an unconscious fluid performance). Introducing intuition at the expert/master level, Dreyfus & Dreyfus supposed a progression from rigid compliance to rules to intuitive reasoning based on tacit knowledge (even though their original paper did not mention "tacit"). However, the model promotes intuition at the expense of analytical thinking (see for example: Gobet & Chassy, 2009) and does not provide any explicit link to action.

The revised Bloom's taxonomy (Bloom et al., 1956; Krathwohl, 2002), approaching skills and competencies according to a classification of learning objectives into three domains (cognitive, affective, psychomotor) makes a link with action by introducing action verbs (analysed in depth by many researchers; e.g. Ven & Chuang, 2005) related to each category;
The model is adapted to align pedagogical objectives with tasks and assessments but it focuses on subjects' changes in behaviour whereas transformation is not addressed. Another limitation of the model might relate to the fact that categorizing cognitive processes into clearly differentiated classifications might undermine the holistic nature of cognition. However, the main issue of the model in association with the present research is that this approach is devoted to a mental activity, remains far from the notion of activity, and cannot thus easily address our concern.

The motor skills model of Argyle & Kendon (1967) was elaborated to explain social interactions considering that social skills operate much like a serial skills motor. The model assumes subjects' motivation is sustained by goals which are achieved through a systematic and progressive loop adjusted by a perceived (perceptive capacities) and integrated (translation) feedback in order to respond to the outcomes of previous actions. The model is graphically depicted in Figure 8.

[redacted]

Figure 8: The motor skills model of Argyle & Kendon (1967).

This model is interesting in that it considers competencies (central box of the graph) coming through actions (the feedback loop) and being achieved within an activity situation, determined by intentions and goals (left side of the graph) and context (right side of the graph). The weakness of this model lies in a lack of descriptive relationships between competencies and action incorporated into the words "translation" and "feedback".

The last model found in the literature is the one proposed by Le Boterf (1998) regarding competencies at work, explicitly associated with work activity. The model relates to action in the way Le Bortef depicted competencies at work involving action through the verb "to act", "*agir*" in French. He defined competencies as a system of three poles: in French, "Savoir agir", "Vouloir agir", "Pouvoir agir". Valdes Conca & de Juana-Espinosa (2012: 234) as other authors referring to Le Boterf's French work, translated as the interaction of three poles: Knowing how to act, Wanting to act, Being able to act**.** This includes a mistake in the translation; the right meaning is: **Knowing to act**, **Wanting to act**, **Being able to act**. This point will be argued later.
The model defines thus competencies as an interacting system of three poles, drawing competencies as a triangle (Figure 9). *Knowing to act* is that the professional will know to implement in situations, whether planned or unexpected provided that it is within the bounds of the profession; this is the practical implementation of the know-how, knowledge, all personal endogenous professional resources which combine themselves in knowing how to act in situations. *Wanting to act* refers to the motivation and the personal commitment of the professional. *Being able to act* reflects the context of the situation of work, the external, exogenous resources of the professional: material means and logistical resources, work organization and the social conditions that make it possible and legitimate responsibility and risk-taking of the professional. *Being able to act* is exogenous by the necessary means to act and therefore by the tools used which may be external to the subject (a hammer) or internal (a procedure known but not necessarily understood or simply the psychological or physiological state). *Being able to act* is therefore also endogenous.

[redacted]

Figure 9: The triangle of the competencies according to Le Boterf (1998).

The model suggests that the analysis of competencies must question the three poles. In French, questions are:

- *Qu'est-ce que vous savez faire?*
- *Qu'est-ce que vous pouvez faire?*
- *Qu'est-ce que vous voulez faire?*

In English, the translation of the questions is:

- What do you know to do?
- What are you able to do?
- What do you want to do?

We must note here that the questioning focuses on "to do" and not "to act". Indeed, in French as well as in English, focusing the question on "to act" would be unclear:
Qu'est-ce que vous savez agir? / What do you know how to act?
or
Comment savez-vous agir? / How do you know how to act?
or
Savez-vous comment agir? / Do you know how to act?

This shows that, to question competencies and therefore, according to the model, to question "to act", we must question "doing" in "action". This is in total agreement with the definitions given by the dictionaries for "*agir*" and "to act". They are similar.
Larousse dictionary gives "agir: faire quelque chose, être en action".
Oxford dictionary gives "to act: do something, take action".
For the pole "Knowing [how] to act", the related question in French is "*Qu'est-ce que vous savez faire?*", neither "*Est-ce que vous savez comment faire?*" nor "*Comment savez-vous faire?*". The English question is thus "What do you know to do?" void of "how". This is why we suggest that the right translation of "*Savoir agir*" is not "Knowing how to do/act" but "Knowing to do/act" despite this is not strictly correct English.

Le Boterf's model therefore suggested the premise of the strong relationship between action and competencies through the verb "to act". We could go further by suggesting that Le Boterf's model is not a model of competencies, but a model of competencies in action. The link between competencies and action is mandatory in order to make competencies visible. According to the review analysis of Coulet (2013: 14), "competencies are manifest in the interaction of a subject (or a group) with a task in a given situation".
In fact, watching a professional sat on a chair and knowing this professional is an experienced and clever worker makes one think that this professional has competencies. In other words, it is not necessary to be involved in action to have competencies or to assume someone's competencies, but competencies are not seen here, just inferred; for the competencies to be seen, observed, it is necessary that the professional summons them within an activity through action.

Le Boterf's model thus appears to be the more suitable for describing competencies in action and is selected for the research. Regarding the research question RQ1 "How are competencies of experienced workers mobilized and how can one access them?", the model suggests that competencies are mobilized through three poles, *Knowing to act, Wanting to act, Being able to act*. However, no experiment is available to validate this assumption; this remains to be done.

To summarize section II-2, it is suggested to select Le Boterf's model to depict competencies in action, the only one providing a relevant relationship between competencies and action. The model explains that competencies combine three poles: *Knowing to act, Being able to act* and *Wanting to act*.

II-3 Methods to access competencies in action

Accessing competencies in action during work activity inevitably refers to work analysis and thus to the cognitive task analysis paradigm which regroups methodologies for job or task design and analysis. Two reviews attempted to provide an exhaustive state of the art (Wei & Salvendy, 2004; Tofel-Grehl & Feldon, 2013) and a categorization of the methods. Moreover, Wei & Salvendy (2004) suggested guidelines in selecting cognitive task analysis methods according to the aim of the studies.

The categorization used in both reviews proposes four main categories:

- Observations and interviews:
  Providing high adaptability, these methods differ from one analysis to another because very sensitive to the protocol adopted (highly structured or not for instance). They are applied in ROS (Real Operating Situations) and are task-focused.
- Process tracing:
  Capturing expertise during activity performance through audio and/or video recording, some methods may include simultaneous verbalization. They are applied in ROS and are task-focused.
- Conceptual techniques:
  These methods "refer to the products of the representations of domain concepts and their structure or interrelations to analysis tasks" (Wei & Salvendy, 2004: 276) providing composite structural representations such as conceptual graph analysis (Gordon et al. 1993). They are indirect methods as not applied in ROS and may focus on conceptual knowledge at the expense of heuristics and strategies.
- Formal models:
  Computational models are developed to describe activities in context and are adjusted after comparison of the results with workers' feedback (e.g. Wei & Salvendy, 2000).

The guidelines in selecting cognitive task analysis methods suggested by Wei & Salvendy (2004) are made up 11 criteria. Some of the criteria regroup several conditions; this is why Table 2 provides 13 points (lines of the table). The aforementioned Wei & Salvendy's categories are given per column and the fulfilment of a criterion suggests adopting one or several categories for activity analysis according to the authors: they are marked by a cross in the table.
The boxes highlighted in yellow identify how the types of activities envisaged to be studied in the present research may be concerned by a criterion: the research aimed at analysing activities in high risk industries with a focus on the nuclear domain, the context of which is well defined (Fauquet, 2006; Fauquet-Alekhine, 2012d; Fauquet-Alekhine & Maridonneau, 2016), sensitive to distraction (Fauquet-Alekhine & Boucherand, 2011, 2012, 2015) and based on knowledge, rules and skills applying well defined procedures (Fauquet, 2006; Fauquet-Alekhine, 2012d, 2013b, 2017a, 2017b, Fauquet-Alekhine & Maridonneau, 2016). We provide here only references to our own work as a guaranty that the characteristics mentioned are actually these of the activities envisaged to be studied in the present research.

Table 2: Guidelines in selecting cognitive task analysis methods suggested by Wei & Salvendy (2004). Crosses in boxes indicate which categories are suitable for activity analysis when concerned by a criterion.

criteria\categories	Observations and interviews	Process tracing	Conceptual techniques	Formal models
the activity domain is well defined		x		
the activity domain is NOT well defined	x			
the activity procedure is NOT well defined	x			
particular process of a task and its concurrent task performance need to be tracked		x		
data is easily captured by verbal means and data collection does not affect activity performance		x		
domain knowledge, structures, interrelations of tasks need to be defined			x	
multiple activity analysers involved, and activity analysis requires less verbalization			x	
activity needs quantitative predication, and models remain stable with context changes				x
activity performance is sensitive to distraction or interference		x	x	x
analysers do not have significant knowledge on analytical techniques	x	x	x	
activity is skill-based	x	x		
activity is rule-based		x	x	
activity is knowledge-based			x	x

Wei & Salvendy's guidelines clearly lead to the conclusion:

the most suitable, for the present study, should be a method based on process tracing.

Among process tracing methods available to date to analyse work activities in the field, one has shown its performance addressing a nearby case to the present study in a PhD framework (Le Bellu et al., 2010; see also Le Bellu, 2011, 2016; Lahlou et al., 2015) based on the early work of Lahlou (1999) and subsequent developments. The method implies miniature camera mounted on helmet for subjective video recordings combined to situated verbalization; recordings are analysed through a protocol based on Subjective Evidence-Based Ethnography (Lahou, 2011) and Perceived Quality Theory (Nosulenko, 2008; Nosulenko & Samoylenko, 2001, 2009). As noticed by others, video analysis may help researchers "to reveal how activities are produced with respect to the contingencies and circumstances of the participants within organizational settings, and examine how the technologies available in these domains are utilized" (Luff et al., 2013: 6.3). A similar digital ethnography technique was applied by Rieken et al. (2015), using a SenseCam, with the objective of analysing a student's day at work in two police schools; the SenseCam was worn around the neck and recorded 1 image every 30 seconds throughout the working day and over 3 days.

Le Bellu's work tried to understand and characterize, from field data, the nature of the transmission and the formalization of knowledge (both explicit and implicit) underlying the execution of professional gestures as part of a given work activity. The final aim was to develop a multimedia pedagogical tool for rare or critical gestures training. This required a refined description and comprehension of the gesture and its analysis in optimal and therefore fully controlled conditions.

Subjective Evidence-Based Ethnography (SEBE) was defined by Lahlou (2011). The SEBE is a family of methods developed in digital ethnography for investigation in social science based on subjective audio-video recordings (the first person perspective: Pea, 1994; Omodei & al., 2005; Knoblauch & al., 2006; Goldman & al., 2007; Petitmengin, 2009; Rix-Lièvre & Lièvre, 2010; Lahlou, 2011) using miniature video-cameras (usually worn at eye-level by subjects: the sub-cam). Recordings are then used for self-confrontation with subjects to collect their subjective experience, discussion of findings and final interpretations between researchers and subjects.

II-3-1 Data collection through video recordings

Using video recordings allows the researcher access to the reality of work activities which is one of the major concerns of work analysts. The use of video has almost become a necessity because the principle of cognitive economy puts subjects in a limited attention and consciousness span that makes it difficult afterwards to recall events from memory only (Lahlou, 2011: 620). According to Rieken et al. (2015: 256), "What can be more easily evaded in discussions becomes difficult to escape when data is brought to the exchange". With the video, "It is possible to identify that what the participant reports they did may be different from what they really did. This is because participants themselves contrast what they remember of a situation with what they recorded during that situation" (p.260) and it allows one "to address practices that were actually captured, not only what they selectively recall" (p.269). The use of video has also become a necessity because it pushes the limits of the classical observation paper / pencil: even with the help of analysis grids, the researcher's writing speed is often much slower than the performance of the task by observed workers. In addition, taking notes entails the risk of not watching the scene for a while and so missing important elements of activity. This could be corrected by replaying the activity but in the world of work, it is generally inappropriate to ask someone to redo/repeat the activity observed several times while video allows for multiple visualizations retrospectively; very useful in the case of complex situations. Furthermore, the fast or slow playback of software players allows a detailed analysis of the recorded observed situation: it is sometimes useful to watch the same scene several times to understand what is happening, or at least make assumptions about what is happening. The video recording is a main tool for self-confrontation: observed subjects seeing themselves in action can learn about themselves and thus correct or improve themselves. These practices of self-analysis and reflection on action promote the development of the meta-functional activities that Falzon defines as the "activities not directly oriented towards the immediate production, activities of construction of knowledge or tools (hardware tools or cognitive tools), for possible later use, aiming at facilitating the execution of the task or at improving the performance" (Falzon, 1994 quoted by Le Bellu, 2011: 107). Thus, the video is both a source and a support: a data source for the researcher and a support of expression (body, speech), of mediation, which participates in the emergence of meaning of the activities and of the co-production of knowledge through the triangle operator-image-researcher (Falzon, 1997).

Along the lines of Vermersch, Le Bellu explored the different points of view for the observation. Vermersch (2010) distinguishes three views possibly adopted by the researcher. According to the psycho-phenomenological framework in which the observer is placed, the point of view in the first person means that the researcher is both source of data and analysis. The researcher studies his/her own experience. The point of view to the second person is summoned when the researcher takes someone other than him/herself as a source of data. Finally, the third-person point of view is adopted when the researcher does not take into account the point of view of the subject and collects only traces of the behaviour. The originality of Le Bellu's work lied in the fact that these three points of view were considered in a frame of different reference, even opposite to that of Vermersch: rather than the researcher (as an observer), it was the subject taken as the centre of the observation device. Therefore, the three points of view did not reflect the researcher's perspective, but that of the subject being the only source of data observable.

For the third person, the researcher uses a classical camcorder, choosing the angle of view and where to position the camera, if the camera is fixed or mobile, the number of cameras in use, when to start, when to stop. All of these choices are a series of filters that determine the result. The external camera in fact records only a selection of the real, pre-emergence of partial, biased and subjective manner, in angles chosen by the observer (Durand, 2001).

The second person is to capture a point of view that is the closest to that of the subject who performs the action, while being piloted by an outside observer with an external camera. In practice, this means

that the observer moves the hand-held camera in the steps of the subject, carrying out zooms so as to be closer to the handling area which lies between the subject and the artifacts (objects, instruments, tools, colleagues, machine, documents, etc.) with which interaction is required. According to Le Bellu, this technique is of relatively little interest as it is an extremely intrusive subject to the observed.
The first person is to use an embedded recording device on the subject in action. The point of view of the camera is then that of the subject: this characterizes the first person or subjective point of view. For this aim, Le Bellu used a sub-cam (or subjective camera), a located shooting device that looks like a camera mounted on glasses, in such a way that it is positioned as close to the subject's line of view. Figure 10 and Figure 11 show a model of sub-cam developed at the London School of Economics (LSE), London by Lahlou in the late 90s (Lahlou, 1999) and a model of camera mounted on a helmet used by Le Bellu in 2010.

Figure 10: Sub-cam developed at the London School of Economics (LSE), London, by Lahlou.
In red circles: the subcam.
Source: Le Bellu (2011): 121

Figure 11: Sub-cam mounted on a helmet used by Le Bellu in 2010.
Source: Le Bellu (2011): 186

The subcam automatically follows the movements of the subject's head. Thus, unlike the external camera, the sub-cam captures the subject's activity according to a first person point of view through the field of view[6] and directly serves the subjectivity of the subject whose activity is studied. According to Le Bellu's work based on the pioneer studies of Lahlou (2006), the sub-cam is an efficient tool to access to the subject's psychology: what/why/how the subject did [what he did], for what reasons, and for which goals. Looking for the capture of the gesture as closely as possible from the subject's point of view, the subcam seeks to capture the subject's vision and hearing. Activities being mostly manual, the target of information sought was within the subject's hands/arms and the technical system manipulated, interactions most often mediated by the use of tools. For most activities, it is not necessary to add an eye-tracking device to detail points of fixation of the eyes: first-person perspective gives a subfilm of the attentional stream of the subject who performs the activity and in the rare moments where this attachment point is ambiguous, the self-confrontation interview with the subject deals with this ambiguity. This allows the researcher to record even what was only visible from the subject standpoint, parts of activity that would not have been recorded by an external camera. In addition, the capture of professional sounds surrounding the subject is important because they are meaningful both in response to actions on the equipment, but also for decisions involving the pursuit of the gesture.

The use of a subjective perspective brought interesting series of improvements on the quality of the explanation by the operator's intentions when rendering in an auto-confrontation interview with the subjective videos (Lahlou, 2006). Le Bellu (2011) and Lahlou et al. (2015) has suggested that this was due to the activation of episodic memory: in the line of Tulving's standpoint (1972, 2002), Le Bellu wrote that it is only memory system that allows people to consciously re-experience past experiences. The trace of the activity offered by the first person perspective can be seen as an ally of memory, when coming back to the recorded activity. Subjects are thus put back into the action which helps them to remember, to rebuild the reasoning applied during the realization of the visualized actions.

Lahlou et al. (2015: 5) explained: "It seems that the more similar the context of memory retrieval is to the context of memory encoding, the better is the recall, and that having multimodal cues helps, especially when they are spatial or motor - see the enactment effect (Engelkamp & Cohen, 1991). In other words, re-living the situation from a first-person perspective would facilitate recalling one's own actions and mental states/processes. This considerably simplifies analysis and interpretation, as well as validating/falsifying research hypotheses."

In her study, Le Bellu combined two video techniques: first-person perspective with subcam on the subject's helmet (Figure 11) and third-person perspective through external recordings by camcorders.

According to Le Bellu's analysis, the limits of such video techniques lie mainly in particular criteria related to industrial plants:

- These environments can be a source of disturbing noise whilst capturing the verbal interactions between colleagues.
- The lack of natural light may affect video rendering and make it difficult to make the following analysis.
- There may be difficulties of evolution or positioning of the external camera according to the available space.
- The use of videos does not imply the absence of a direct observer whilst the subject performs the activity.

[6] The visual field is the spatial array of visual sensations available to observation in psychological experiments form the standpoint of introspections (Smythies, 1996). Visual field must not be confused with the field of view, which is everything that causes light to fall onto the retina at a given time (input), processed by the visual system, and computes the visual field as the output.

II-3-2 Data analysis through confrontation with subjective video

Analysing data within the SEBE framework implies confronting the subject to the subjective video through a replay interview. This stage of the analysis is essential since according to Leplat (2000), observing activity says little about the intentions, considered options and the mental operations of the subject. Hence video data are not sufficient to achieve the objective of capitalization and transfer of knowledge. In particular, they give no information about the subject's perception neither of the situation nor of the element of the work context that guide decision-making processes. Moreover, they give no direct access to non-observable knowledge, which seems inaccessible because tacit.
Confronting the subject with the subjective video as done in the SEBE framework refers to situational approaches in that they favour the setting in the foreground of the subject in a situation. They are opposed to non-situational approaches which adopt a more distant view of the situation by providing methodological tools more centred on reports or preparations of activities and/or past and future events.

We shall not describe non-situational approaches here as they do not concern the SEBE approach. For information, we shall just mention some of them: structured, semi-structured, and unstructured interview, focus groups (Coolican, 2009; Crane & Hannibal, 2009), storytelling (e.g. Denning, 2004; Garcia-Lorenzo, 2010), instructions to an alter-ego (Oddone et al., 1981).

Situational approaches in which we are interested imply verbalizations of the activity by the subject. They are distributed in two categories of techniques: simultaneous verbalization and consecutive verbalization[7]. Some techniques may be combined.

Spontaneous verbalization & Thinking aloud method (simultaneous verbalization)

Spontaneous verbalization as well as the Thinking aloud method (simultaneous verbalization types) aim at bringing subjects to describe the procedures they use to carry out their task for the former or at verbalizing the psychic processes related to the realization of the main task "step by step" (Newell & Simon, 1972) for the latter. Simultaneous verbalization by the subject occurs whilst performing the activity. It is possible to characterize the degree of requirement that the researcher gives to the verbalization (Leplat & Hoc, 1984). Generally, simultaneous verbalization to action has the advantage of not being disconnected from the performed activity. But verbalizing involves the completion of a double task and two goals by the subject: to carry out the work (main task) and to comment on what is done (secondary task) according to the guidelines given by the analyst. The main task may be slowed down and amended, in particular when the activity is highly automated. Activity thus loses its spontaneity and efficiency.

Consecutive verbalizations

Consecutive verbalization comprises mainly four techniques: self-confrontation, cross-confrontation, explication interview, and subjective replay interview. Consecutive verbalization by the subject occurs after performing the activity. These techniques intend to put an individual or a collective in reflexive position on their own work activity or that of colleagues. The goal is to make them aware of explicit or tacit knowledge and know-how or to develop/adjust/improve them.

Self-confrontation

Self-confrontation was developed by Von Cranach (1982), and then, on the basis of this work, by Theureau (2002) as a method of investigation of human activity in the framework of his theory of goal-oriented activity. Von Cranach identified three inter-dependent levels of action, each being recoverable by a specific method: (1) the ongoing behaviour (acts) are

[7] Other techniques may be of anticipated verbalization types. It is the case for some of the non-situational approaches.

recoverable through audio-visual observation techniques; (2) the cognitive level guiding action is recoverable by a self-confrontation of the actor; (3) the organizational and social action (representations) is recoverable through the confrontation with other actors (see “cross-confrontation” below). Self-confrontation is a deferred examination of the dynamics of structural coupling subject-situation supported jointly by means of reproduction of behaviour (e.g., video) and by the researcher as both observer and interlocutor (Theureau, 2002). Rieken et al. (2015: 255) applying self-confrontation during digital ethnographic studies for day-work analysis (image-recording of an activity with post-analysis during interviews with subjects, developed further), mentioned introspection as a process occurring during self-confrontation. They even suggested that social components of introspection could be considered within a collective approach rather than limiting interviews to an egocentric dimension. Similarly, Lalhou (Lalhou , 2011; Lalhou et al., 2015) and Le Bellu (2011, 2016), also applying digital ethnography for activity analysis, mentioned introspection when describing psychological processes during interviews. Therefore, the notion of introspection needs to be developed here for two reasons at least: the first is that specialists of digital ethnography seem to observe or apply introspection during their studies, the second is that this notion is not so simple and introspection takes different senses from one research to another as we shall see further.

Cross-confrontation

Cross-confrontation is derived from the work of Clot (Clot, 1999; Clot, et al. 2001) and then Mollo & Falzon (2004) who rather call it “cross allo-confrontation”. This technique seeks to create a framework for the development of the professional experience of the collective in two phases: Phase 1) Constitution of the analysis group that determines the sequences of activity to record. Each subject individually faces his/her own recording of activity. The recorded interview is structured by the researcher. The comments of the subject are a way to bridge the gap between the activity actually carried out by the subject and the professional genre (Clot, et al., 2001). Phase 2) Cross-confrontation, also recorded, which brings together the researcher and two subjects around a recorded video of the activity of each of the two protagonists. By this technique, each subject is faced in turn with the comments of the colleague. The styles within the activity are discussed, shaping the genre which in turn reshapes the styles (Clot, et al., 2001). These different sequences provide development and awareness. A movie editing is then elaborated to present and extend the analysis to the professional collective. The use of the collective's work allows one to highlight the knowledge and representations that are shared or not by the group and seems to favour a higher level of consciousness (Mollo & Falzon, 2004).

Explicitation interview

Explicitation interview (Vermersch 1994) is a descriptive verbal implementation of action experienced by a subject. This implementation may be based on material or activity traces. The technique offers a framework and guidelines to lead the researcher in how to conduct the interview, and through this questioning, to make the subject aware of the action and of the way it was performed. Vermersch distinguishes four stages of awareness: (1) the singular experiences, inscribed in action (pre-thought), (2) represented experiences (work of 'reflection'), (3) themed experiences through words, and (4) experience as an object of knowledge (by thinking). Thus Vermersch distinguishes the “pre-thought awareness” or “direct consciousness” (implicit knowledge which refers to the tacit knowledge of Nonaka), from the “thoughtful consciousness” (explicit knowledge). Awareness from what one is conscience of during the action, goes through a cognitive awareness operation that has to be provoked. The technique of questioning may be seen as introspective; the goal is to stimulate recall of memories stored in so-called "retention", "emotional", "episodic", or even "autobiographical" memory. The latter provides access to the personal experiences of an individual within a certain limit of time and subjectivity.

Subjective replay interview

Subjective replay interview or more simply “replay interview” (Lahlou, 2011) takes from techniques of self-confrontation and explicitation interview. This method is similar to the cued recall debrief developed by Omodei & McLennan. (1994) and applied by others (see for example Bentley et al., 2005, Rix & Biache 2004). It aims at explaining the subjects’ activity based on the video recording of their activity according to a subjective situational point of view. Subjective video is used as a medium of consecutive interview: particular sequences of the video are chosen by the researcher and subjects are asked to comment on them. During the subjective re-situ interview, the objective trace provided by the video recording constitutes a stable and reliable basis for the production by the subject of a comment relating to his/her activity and more precisely relating to the act viewed in situation (Theureau, 1992; Rix & Biache, 2004). The associated cognitive process is well described by Lahlou: “The sub-cam provides material that is especially relevant for the reconstruction of the mental activity. Experience shows that subjects are often able, even weeks after the fact, to recall the situation very precisely. We can check whether this is not a reconstruction by asking the subject ‘what will happen next’, and then compare with the actual action on film. This recall effect is probably due to the nature of episodic memory (Tulving, 1972, 2002). While semantic memory recalls general relations between objects, episodic memory is a multimodal association connected to an actual lived event (time, place, associated emotions, intentions, contextual knowledge and other associations), which come back as a bundle when the subject recalls the event. Viewing his own film, when put back into an exact relationship with the actual lived sequence, the subject is naturally induced to recall this sequence. Getting multimodal cues allows much better recovery of the events experienced […]. At this stage, it is possible to have access to the thoughts and emotions of the subject (Bentley, Johnston & Baggo, 2005) even weeks later, a delay often needed for the analysis and arranging an appointment with the subject. Such an effect is observed with classical film recording, but not to the same degree as with the subcam” (Lahlou, 2011: 623). What is specific in the replay interview as practiced by Lahlou and the SEBE group is the use of activity theory and situated and distributed cognition in the formulation of the questions asked to the participant, which make the participant explicit the goals, motives, and influence of the affordances provided in situation in the construction of action.

Introspection

For Danziger (2015), in a first approach, introspection may simply refer to “the self-observation of mental events”. Stated in other words by Vermersch (1994: 203), “the access to knowledge of one’s own cognitive functioning may be in a general manner considered as an act of introspection”. Written this, any attempt to access (and additionally to understand) what happens or what happened in a subject’s mind is introspection. When understood in this way, psychoanalysis is introspection, as is self-confrontation. We refer to this type of introspection as “macro-introspection” in the following.

However, for a large part of the scientific community, introspection addresses a more complex psychological process. In his 2006 paper, Overgaard provided an interesting synthesis of what is introspection and how it may be applied. Confronting arguments of renown fathers of this concept (Brentano, Comte, James and Wundt), he concluded that “introspection” is the access to one’s inner mental state by oneself (p.630) and “involves an attending to the content of one’s consciousness and nothing more than that” for which “the use of an introspective report about the relevant state seems the only possible methodology” (p.631).

Overgaard (2006) pointed out a first controversy in that, according to Wundt, introspection was an active observation whereas according to Brentano, introspection had to be a "passive inner perception" so as to avoid "destroying the introspective experience" and thus provide reliable reports (p.630-361), confirmed by James' analysis advocating that "active observation of mental states may change or destroy the first-order content" (p.630).

Hence a second controversy rose about the possibility to do so. Overgaard (2006) reported that Comte tried to demonstrate its impossibility through the argument that a subject cannot split in two parts "so as one part observes the other" while James tried to bypass this problem by turning "introspection" into "retrospection" implying "*not* to accept introspection of currently conscious states" (p.630). This challenging point led to many studies especially addressing subjects' verbal reports as valid introspective reports; many of these studies based on the correlation between verbal reports and objective behavioural data related to the same event. To date, the resulting conclusions remain non-categorical. However, Gailllard et al. (2006) suggested another perspective than this binary approach: referring to Ericsson and Simon's work (Ericsson & Simon, 1980), they insisted on the fact that the main issue was not about acceptability (or not) of verbal reports overall and suggested considering instead the circumstances of acceptability. On the one hand, subjects' concurrent verbal reports (as thinking-aloud, not explaining) to access their mental state whilst performing the task might anyway interfere with the cognitive process or decrease the speed of performance of the activity (Nisbett & Wilson, 1977; Ericsson & Simon, 1980; Ericsson, 2003). On the other hand, subjects' retrospective verbal reports might lose in reliability due to an inaccurate or partial recall (Gaillard et al., 2006). Many authors advocated for combining systematically verbal reports and objective measurements so that to ensure they seize not only what was reported but all that was reportable (Gaillard et al., 2006: 713). In addition, retrospection might generate the subjects' interpretation or speculation about their own cognitive processes making it difficult to accept verbal reports as objective and thus acceptable data. However, as mentioned earlier, circumstances under which verbal reports are obtained must be considered, implying that all concurrent or retrospective verbal reports cannot be invalidated from the outset. Two experiments (original and replicated) illustrated it clearly. Bechara et al. (1997) studied the subjects' consciousness of self-performance during a simple gambling task (the ''Iowa gambling task'') by comparing their skin conductance (continuous objective somatic measure) to verbal reports obtained through periodical questioning (subjective data). The task consisted in choosing a card among four decks and maximizing gains on a series of trials, a card resulting in a win or a loss when playing for money. Unknown to the participants, some decks were advantageous, as opposed to others. They found out that subjects started selecting cards from advantageous decks and skin conductance increased just before selecting a disadvantageous card before the subjects were able to verbally explain their choice. This situation of dissociation between performance and verbal reports could be interpreted as evidence of unconscious knowledge accessed through introspective verbal reports and confirmed by objective data. This experiment was replicated by Maia and McClelland (2004) who used a more elaborate questionnaire. Doing so, they found out that the dissociation vanished and they concluded that there was no evidence of unconscious knowledge, thus invalidating the introspective character of the original experiment. However, we might also consider, as highlighted by Overgaard (2006) and others and reported above, that the original experiment complied with the introspection need to put the subjects in a "passive inner perception" by using simple questions. On the contrary, using an elaborate questionnaire, researchers of the replicated experiment implemented an active observation of mental states and destroyed the introspective experience. Simple questions induced simple answers conversely to elaborate questionnaires. This echoes Titchener's viewpoint (as reported by Danziger, 2015), who was "a major exponent of experimental introspection", and who "demanded that introspective descriptions should be in terms of simple, irreducible units and should abstract from any meaning that the stimulus might have" (p.703) since "additional cognitive activity must necessarily change the sequence of mediating Thoughts" (Ericsson, 2003: 11). Ericsson undertook an analysis regarding factors decreasing validity of verbal reports: "The first arises when the investigators try to obtain more information than the subjects' thought sequences can provide. […] Second, investigators often ask the subjects to describe their methods for solving problems at the end of the experiment, when they have completed a long series of different tasks. If the subjects generated and consistently applied a general strategy for solving all of the problems, they should be able to respond to such requests easily with a single memory retrieval. But the subjects typically employ many methods and shortcuts and even change their strategies during the experiment, through learning. Under such circumstances, the subjects would have great difficulty describing a single strategy used consistently throughout the experiment, even in the unlikely event that they were motivated and able to recall most of the relevant thought sequences. It is therefore not surprising that the subjects' descriptions are imperfectly related to their averaged performance during the entire experiment" (Ericsson, 2003: 15). The main factor explaining the different results between the original and the replicated experiments was thus the circumstances for obtaining the introspective verbal reports. This also led to the assumption that analysts may have an introspective approach with the aim of obtaining introspective verbal reports from subjects about whom they intend to access the mental state but they may be unable to create favourable conditions for introspection. According to Gaillard et al. (2006: 714), "authors widely agree on the validity and on the reliability of verbal data as a source of information about cognitive processes as long as they are elicited with care and interpreted with full understanding of the circumstances under which they were obtained".

Gaillard et al. (2006), after reviewing and discussing results regarding the contribution of introspection in the process of implicit learning, suggested three criteria to validate the acceptability of verbal reports as introspective:

- instructions given to subjects for verbalization in either a general or a specific manner must not have any effect on the introspective cognitive processes (limiting the subject's answers to a few possible categories such as ''yes'' or ''no'' or, on the contrary, forcing subjects to produce elaborated and exhaustive description might limit or spoil the introspection process),
- verbal reports must be complete, consisting of all the information the subjects have about their own cognitive processes,
- verbal reports must be consistent with other empirical data on behaviour.

However, the last point should be considered as a bilateral relationship: if empirical data on behaviour leads to validating verbal reports, similarly verbal reports lead to explaining empirical data. This is well illustrated by the ''Iowa gambling task'' experiment reported above: verbal reports were corroborated by the existence of variations of skin conductance and variations of skin conductance were explained by verbal reports; without verbal reports, researchers would have perhaps never known that variations of skin conductance were related to an unconscious knowledge of advantageous decks. In the same vein, Ericsson (2003) mentioned a mental calculation task for which concurrent verbal reports helped to identify intermediate products during the cognitive process. The occurrence of cognitive phases related to intermediate products could be associated to sequences of eye-fixations through eye-tracking for example; in this case, concurrent verbal reports regarding the intermediate products would be corroborated by sequences of eye-fixations observed, and similarly sequences of eye-fixations observed would be explained through verbal reports. Beyond the psychological observations to provide objective data, neuroscience through fMRI contributed to provide evidence of introspection effectiveness through attempts to describe the neuro-mechanism underling this phenomenon: Flemming et al. (2010) showed that abilities at introspection were correlated with the bigger volume of white and grey matter in the brain; more recently, Baird et al. (2013) revealed a behavioural dissociation between two metacognitive abilities suggesting that subjects good at reflecting on memory might be poor at reflecting on perception or vice versa and that these abilities were related to the functional integrity of unique neural networks anchored in the medial and lateral regions of the anterior prefrontal cortex.

In their attempt to format the validation of the acceptability of verbal reports as introspective, Gaillard et al. (2006) forgot the influence of time, perhaps because it was implicit for them:

- verbal reports must be concurrent to the task performed to relate to introspection.

If this criterion is not respected, Gaillard et al. (2006: 713) use the expression "retrospective verbal reports" (shared by other researchers) potentially suffering from a bias due to the fact that "subjects may forget or inaccurately recall the relevant features of the experimental situation, which of course cannot be interpreted as implying that they were unaware when engaged in the task." For these retrospective verbal reports to be considered similar to introspective verbal reports, Ericsson (2003: 13), on the basis of a prior review, suggested that the time to generate these reports had to occur less than 5 seconds after the event described so that "the participants can recall their sequence of thoughts reasonably accurately". However, as we shall see when discussing the results of the present study, Gaillard forgot this time criterion perhaps because it characterizes more the way verbal reports were obtained than their validity.

As we can see, applying introspection during work activities implies concurrent verbal reports. Authors qualify the investigation as retrospection or indirect introspection as proposed by Titchener (Titchener, 1912 and Kriegel, 2013: 1172) when performed during interviews in an attempt to access mental states (see also Piccinini, 2003: concurrent introspective reports and retrospective introspective reports). Nevertheless, implementation does not seem easy whether it be for introspection or retrospection. The available studies regarding digital ethnography for activity analysis and mentioning introspection (Lahlou, 2011; Lahlou et al. 2015; Le Bellu, 2011, 2016; Rieken et al., 2015) suggested summoning macro-introspection (as defined at the beginning of the present paragraph "Introspection") and did not provide any evidence of direct or indirect introspection. In addition, during replay interviews of these studies, the mental states identified appeared to be a product of remembrance as well as reconstruction (Lahlou et al., 2015: 2) rather than from direct or indirect introspection although this did not prejudge the occurrence or the absence of the latter.

After a review of different methods applied to work activity analysis through video recordings, and after a series of tests (Le Bellu et al., 2009), Le Bellu opted for the simultaneous verbalization during some (but not all) video recordings and consecutive verbalization using subjective re-situ interview. The simultaneous verbalization integrating the Activity Theory approach was called "simultaneous goal-oriented verbalization". The questioning during consecutive verbalization of the replay interview and the following analysis were essentially based on Activity Theory and Perceived Quality Theory presented in the next section.

II-3-3 Description of Le Bellu's SEBE/PQT-based protocol

With the aim of obtaining a refined description and comprehension of professional gestures to integrate a teaching multimedia system, Le Bellu (2011) tested two protocols, one devoted to the capture of the gesture in a real operating situation, and one capturing the gesture in a re-created operating situation.

The capture of the gesture in a real operating situation was structured in six steps:

1 Framing.
2 Capture (sub-cam and camcorder) of raw gestures not commented on.
3 Pre-analysis of the gesture if possible, depending on the availability of participants.
4 Subjective re-situ interview (verbalization retrospectively, restoring the meaning to the gesture).
5 Analysis, video editing and formalization of the multimedia pedagogical tool.
6 Validation of the multimedia pedagogical tool by professionals.

The re-created operating situation differed from the real operating situation in that:

- The situation was prepared before the capture in order to optimize the parameters determining the quality of the video recording (subjective as well as external).
- The worker was prepared for simultaneous goal-oriented verbalization during the video recording through preliminary exchanges with researchers and a first "shoot" of the activity without verbalization.
- A pre-analysis of the gesture and a film editing lasting about two weeks before the subjective re-situ interview.

- The protocol involved a third video recording of the activity offering, after the two first recordings, the benefit of a higher level of mentally structuring during activity realization.

The capture of the gesture in re-created operating situation was structured nine steps:

1. Framing.
2. Capture (subcam and camcorder) of the raw gesture not commented (first shooting). This capture helped researchers to understand the essence of the gesture and highlighted the kinetic scale and pace of the task scale.
3. Mental preparation of the worker (mental structuring of the gesture to restore the meaning).
4. Capture (subcam and camcorder) of the structured gesture commented through simultaneous goal-oriented verbalization (second shooting).
5. Capture (subcam and camcorder) of structured gesture commented and mentally structured (third optional shooting).
6. Pre-analysis of the gesture and video editing.
7. Subjective re-situ interview (for complete check, first-level validation).
8. Final analysis and formalization of the multimedia pedagogical tool.
9. Validation of the multimedia pedagogical tool by professionals.

After testing the two protocols and with regard to her research goals, Le Bellu concluded that the capture of the gesture in a real operating situation had "the advantage to be closer to the reality of the field. On the other hand, this was more restrictive, less reliable, and heavier from the data collection and analysis standpoints" (Le Bellu, 2011: 226). When analysing the limits of this method, she pointed out that:

- The method is well suited to certain gestures, including simple gestures, but complex gestures require adjustments of the method. This is particularly the case of collaborative activities, or those for which the kinetics is too fast, as well as non-manual gestures (e.g. observation activities, preparing a task in an office).
- Taking account of temporal factors and distributed tasks over time and between people is not possible.

One of Le Bellu's conclusion was that "Research work remains to be undertaken regarding collaborative and non-manual gestures in order to adapt, modify or even redevelop a method which permits to capture, analyse and formalize these types of gestures" (Le Bellu, 2011: 358).

At this stage, it was assumed that this method had to be adapted to the need of the pre-set study.

However, in order to demonstrate the effectiveness of the resulting adapted method, the outcomes (knowledge and know-how identified) and the way they were obtained in terms of efficiency had to be compared with other methods. The organization of the nuclear fleet of EDF SA provided three other methods applied in different contexts which will be described thereafter when needed. These methods providing data with the same objective (describing what the competencies of experienced workers are) are the SAT method within the framework of an action program named "Competencies Program", the SAT method combined to a description-based method and the Self-confrontation.

The SAT method within the framework the "Competencies Program":

> In 2012 an action program named "Competencies Program" (EDF, 2013) was launched for the French nuclear fleet at national level. An analysis carried out by Human Factor Consultants in 2014 (Fauquet-Alekhine, 2014b) on this program showed that innovations of this program remained in three points: i) ask for the experienced workers to be more involved in the training sessions inside the training centres, ii) ask for the Operations departments to organize "Training commissions" in order to analyse in depth the need in terms of training for each profession, iii) develop training tools on the basis of new Information & Communication Technologies. The "Training commissions" are the organizational tool aiming at analysing work activities in order to identify exhaustively what is needed in terms of training to help workers

elaborating expected competencies for the activities. The “Training commissions” are meetings in room summoning experienced workers, managers, and pedagogical supporting analysts of the training centre. A first meeting identifies which activities are relevant to be analysed. A second meeting is devoted to the analysis of a given activity. According to the SAT method, a Systematic Approach to Training developed in 1998 by the International Atomic Energy Agency (IAEA, 1998a), all the participants break down the activity and identify knowledge and/or know-how necessary to perform the activity. In addition, the method is iterative: when an activity is analysed at the national level, the corresponding results may be improved by a new analysis on a plant, and again on another plant. The objective of this is to lead to improvement in the professionalization strategy regarding the analysed activity by adding/removing some parts of the related training, and improve training through suggestions. The huge database regroups the findings of these analyses, identifying knowledge and know-how per activity.

The SAT method is not confined to nuclear industry: different versions of the method exist in medicine for instance (e.g. Yao et al., 2010; Nestel et al., 2014) or in Information & Communication Technics (e.g. Martinie etal., 2011).

The SAT method combined with a description-based method:

This method uses the results of the SAT method for a given activity as described above and adds an addition discussion stage between an experienced worker of the profession concerned by the activity to be analysed and then trained, the management and the trainer. As for the SAT method, it remains a work analysis undertaken around a table between experts. The added value compared with the previous method is that it may highlight issues specific to the profession and the activity which would not have been identified at the national level.

The Self-confrontation:

This method was described in the literature review. We shall now recall its main traits. It is based on the analysis of the first-person video recording of the activity: after performing the activity during which the subjects were equipped with a video recording device, they individually watch a video recording of this activity with the researcher who questions them about how they performed the activity. In the case of subcam, seeing themselves in action from their own point of view involves them in a self-analysis and reflection on action which promotes the development of the meta-functional activities for possible later use, aiming at facilitating the execution of the task or at improving the performance. The video is both a data source for the researcher and a support of expression, of mediation, which participates in the emergence of meaning of the activities and of the co-production of knowledge through the triangle operator-image-researcher (Falzon, 1997). This method is applied at the Chinon NPP for debriefings of simulation training sessions by some trainers on the basis of third-person video recordings. However, usually, results are kept confidential for the team being trained and hence are not shared with other teams.

To summarize section II-3, the Cognitive Task Analysis paradigm led to select a method for accessing competencies in action: a “process tracing” method. A refined analysis of this sort of approaches oriented the choice towards a method based on first-person video recordings of activities followed by re-situ subjective interviews

II-4 Elaborating and applying competencies in high risk industries

The KKHS synthesis clearly illustrates the need of applying competencies in actions and the specialized nature of competencies since they are related to the work situations. This suggests that being competent in simulated situations does not mean being competent in real operating situations: a transference process is needed to transform competencies for simulation in competencies for real operating situations.

Capturing or identifying what makes up the competencies of experienced workers is thus a key step for training but simulation training must include a step of transference.

This is achieved through the simulation debriefing during training and through mentoring. Simulation training must be designed in this perspective. However, few models are available for the description and the improvement of the simulation session design.

II-4-1 Simulation session debriefing

For many years now, the scientific literature as well as the simulation training practices have tended to focus on detailed descriptions of the action phase in the simulated sessions, forgetting how the reflective phase could be important for the learning process, especially through the debriefing (see for example Northcott, 2002; Brackenreg, 2004). This was probably due to the fact that the designers were engineers, experts in the industrial technical process rather than in the pedagogy of training.

However, the debriefing of simulation sessions has been highlighted as a key part of the transference process between simulated situations and real operating situations by many specialists in simulation training (Issenberg et al., 2005; Fanning & Gabba, 2007; Anderson et al., 2012) for several years now. As written by Fanning et al. (2007), "although reflection after a learning experience might occur naturally, it is likely to be unsystematic." Rudolph et al. (2006) pointed out the importance of analysing performances within a context of both trainers and trainees: people then make "sense of external stimuli through internal cognitive frames, internal images of external stimuli." Debriefing allows discussion of the non-action which is definitely a part of the real of the activity: "not doing anything, or perhaps better stated, continuing to sit or stand but not moving elsewhere, is itself an action" (Clancey, 2002). It must be understood that without debriefing, the risk would be to limit the simulation session to the "realized" of the simulated activity which is different from the "real" of the simulated activity. Non-actions (considered as parts of the real of the simulated activity) are potential or possible actions not done but which might have been done, and are usually not observed; the debriefing may help to reach the level of non-action (Fauquet-Alekhine & Labrucherie, 2012).

In order to exemplify the benefits of the debriefing session, an example is given hereafter describing a sequence on a simulator for nuclear reactor piloting followed by the corresponding sequence in debriefing (excerpted from Fauquet-Alekhine & Pehuet, 2016:73 and 78).

> Sequence on simulator:
> The operator-pilot faces the control panel and is about to make a regulation of the scram position. He must adjust the reactor neutron power to the level requested by the electrical network. Before handling joysticks, he says out loud what he intends to do in the presence of the technical manager who is right behind him. The trainer benchmarks this approach as a crossed control; according to him, this professional practice allows one to make the action reliable before acting as it is to be seen, before the action is performed by the technical manager, who has an overall wider vision of the state of the installation than that of the operator-pilot. […] The trainer does not know whether the operator is aware of implementing a reliable practice or not. He notices therefore this point, identifies the sequence on the video recording in order to have a re-discussion during the debriefing.
>
> Sequence in debriefing:
> When the operating team is asked to detail what was done for the neutron power adjustment, the operator-pilot, who was piloting control rod assemblies explains his technical gesture […] what. The trainer encouraged him to say what was just done before; the operator-pilot explains that he analysed the situation to choose what action was adapted, he announced to his colleague operator-pilot the planned load decrease, and that he manipulated the control equipment. Is this all? The operator thinks "Yes", it was the main thing. The trainer then asked the other trainees where they were at this time. The technical manager remembers having been just behind the operator. The trainer therefore asks the question again: what happened before the action on the joysticks? The technical manager remembers how the operator-pilot explained to him what he was going to do, and the details return to the operator's memory. The trainer suggests a deeper exchange between the participants by questioning these elements of activity, apparently so common that they became invisible. This is for everyone to put into words what has been

done, what was brought by each for oneself and for the other, and what each learnt from what the other did. The conclusion of the team is clear: for the power setting, when the operator-pilot says out loud what he intends to do in the presence of the technical manager just behind him, this contributes to ensuring what will happen after more reliable: discussion between workers forthcoming actions anticipates the risk of error. The trainer then leads them to wonder about the difficulty they had to remember these "details": the general answer is that "it is natural" and therefore nobody thinks about that anymore.

This example shows how the debriefing was necessary to make the trainees aware of what they did in order to share it: “In this type of debate, the trainer brings trainees to re-examine what is agreed in practice, and encourages pilots to set their personal style. It allows them to be aware of what they are implementing in the work activity, and possibly to make it available for others: being conscious in order to transmit to others” (Fauquet-Alekhine & Pehuet, 2016: 79).

Models were developed to understand and improved the learning and transference process occurring during debriefing. Fanning & Gabba’s model (2007) suggested a three phase debriefing: a reaction phase during which trainees ‘‘blow off steam’’ and give the instructor a preview of their concerns, an analysis phase of trainees’ performance with discussion, and a summary phase elaborated by trainees, gathering lessons learned from the situation experienced for future performance. These three phases were later renamed by Zigmont et al. (2011) as “defusing, discovering and deepening” in order to give what they called the 3D model of debriefing. Fanning & Gabba’s model was based on the earlier model of Lederman (1991) who suggested a three steps approach: i) introduction to the systematic reflection and analysis, ii) intensification and personalization of the analysis of the experience, iii) generalization and application of the experience.

More recently, an optimal design for the debriefing was proposed and tested in nuclear industry, named debriefing 7S2P (seven points and two principles). This work (Fauquet-Alekhine & Boucherand, 2016b) was based on previous collaborative studies (Fauquet-Alekhine & Pehuet, 2016).

This protocol completed and refined in seven steps the debriefing model of Fanning & Gabba (2007) based on the earlier model of Lederman (1991), later improved by Rudolph et al. (2008) and successfully applied by others (see for example Gardner, 2013). Fanning & Gabba suggested a three-phase debriefing: a reaction phase reducing trainees’ emotional stress and giving trainers a preview of their concerns, an analysis phase and discussion of trainees’ performance, and a summary phase gathering lessons learned from the experienced situation for future performance.

- First step: reminder of the ethics concerning the whole training session and particularly the debriefing. This crucial step recalls general considerations regarding the atmosphere of the debriefing (well summarized in the review of Fanning & Gabba (2007: 116)) promoting a non-judgmental approach: “To ensure a successful debriefing process and learning experience, the facilitator [the person hosting the debriefing] must provide a ‘supportive climate’ where students feel valued, respected, and free to learn in a dignified environment.” Participants need to be able to “share their experiences in a frank, open and honest manner.”
- Second step: expression of the trainees’ expectations and perceived goals of the training session. The final comparison between expectations and what has been done helps participants to leave (and come back) with a positive attitude.
- Third step: trainees’ feelings regarding the simulator run. When the situation involves several trainees for collective activities, allowing discussion of possible interpersonal difficulties that occurred during the simulator run, this helps deal with eventual consecutive emotional issues.
- Fourth step: reflexive analysis of the simulator run. This refers to the ‘reflection on action” of Schön’s theory (1987). Subjects reflect after the encountered situation and examine what/how they acted, thought through the problem, which options they chose or which they did not. During this step, the principle of generation effect consisting of making the trainees

produce the narrative by themselves is fundamental. This time was also used to clarify technical points according to subjects' questions (Middleton, 2012).

- Fifth step: comparative analysis between what had been experienced during the simulator run and what should be encountered in the future operational situation. We referred to this as the "projective perspective": it projects the subject in the future activity and considers what should be done in such forthcoming situation. This was mainly shaped by the principle of projective perspective but also by the principle of generation effect as this was obtained by the researcher's questions which were answered by the subject.
- Sixth step: additional needs in the perspective of transference for the future activity. Subjects were asked whether they needed additional help about any point or not.
- Seventh step: concluding remarks ending the debriefing highlighting what the training brought to the subjects, asking the subjects to compare this with the expectations expressed in step 2, and summarizing the subjects' intentions. This dealt with the fact that trainees often have difficulty recognizing the rich learning benefits from the training session (Middleton, 2012).

Two key principles completed the protocol: the generation effect and the projective perspective which benefits have been quantified as generative and adaptive learning process (Proctor & Gubler, 2008).

- The generation effect principle aimed at making the trainees produce the material to be discussed, the findings, the solutions and related assessment or admissibility by themselves. Debriefing must ensure that the trainees have "discovered and evaluated their own solutions, rather than being told by the leader" (Thiagarajan, 1980: 10). The Generation effect was facilitated in this case by the trainer (the researcher) questioning the subjects' narrative, findings and solutions. The generation effect was fundamental during the fourth, fifth and sixth steps described above.
- The projective perspective principle aimed at bringing the subjects to project themselves into the future activity on the basis of what they had just done, helping them to think about what should be done in the forthcoming situation. Subjects were thus preparing for the future task by refining the mental representation of the future expected results. The projective perspective was fundamental during the fifth and sixth steps described above.

This 7S2P debriefing has shown excellent efficiency whilst performing a simple technical task with two samples of subjects (experienced and novice) and proved that a gain of up to 33% in job performance could be expected (Fauquet-Alekhine & Boucherand, 2016b). Analysis highlighted how applying the protocol could compensate a novices' lack of experience with their final performance being slightly less effective than those of the experienced subjects were. The results have been successfully explained in the light of the revisited Rasmussen model (1983) and Kolb's experiential learning model (1976, 1984).

II-4-2 Simulation session design

Simulation may take different forms of training depending on the general pedagogical goal. These may be initial training, development or recycling periods, training in the application of special procedures such as those that allow one to deal with potentially risky situations, or the work of rare situations (Geeraerst & Trabold, 2016, Vidal-Gomel & Fauquet-Alekhine, 2016). The general pedagogical goal is usually linked with the population to be trained: a novice does not have the same needs as the experienced worker. The novice will not be trained as an experienced worker and hence the novice, becoming experienced with time, will be trained differently along his/her career path in the professional training process. Considering the simulation training as part of a whole professional training process, Samurçay (2005) described the case of nuclear reactor pilots involved in a course in three stages, the first two addressing the novices: technical training with epistemic goal including academic lessons and part-task simulation training for basic operations, full scale simulation training whose aim is to elaborate integrated competencies for operations. These two stages (lasting several months) are prolonged by recycling trainings (a few days each) on full-scale simulator several times a year. The same is done for the aircraft pilots (Jouanneaux, 2005; Labrucherie, 2011, 2016).

According to Samurçay (2005), simulation training must be considered not isolated but as part of a whole professional training process in order to be more accurate regarding the professional competencies which are sought. In other words, within such a process, simulation training has input data mainly determined by the trainee types, pedagogical goals, and output data such as knowledge and know-how, elaborated in simulated situations to be adapted in real operating situations, the final goal being to achieve professional competencies. Yet, to improve the input data, both professional competencies and what makes professional competencies must be identified and understood to foster the pedagogical goals and the training programs. The occupational training process of Samurçay is a loop that may be drawn according to the Kolb's experiential learning theory (Kolb, 1976; 1984). The model (Figure 12) combines a four-stage learning cycle and four distinct learning styles.
The four-stage cycle of learning are i) Concrete Experiences providing a basis for ii) Reflexive Observations, which are distilled, when assimilated, into iii) Abstract Conceptualization producing new implications for action in iv) Active Experimentation (testing implications of concepts in new situations) creating new experiences available for application in i) Concrete Experiences.

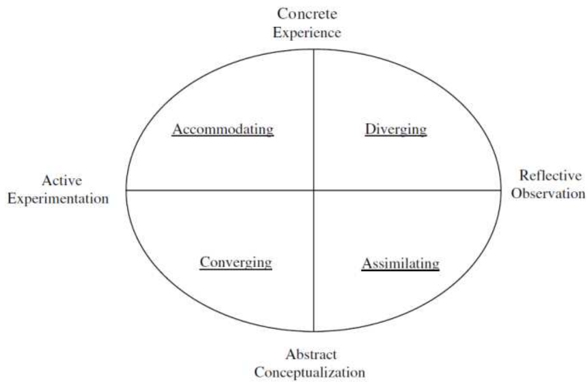


Figure 12: Kolb's Experiential Learning Theory model (ELT model); source: Kayes, Christopher-Kayes & Kolb, 2005.

The four distinct learning styles are defined according to the author are follows (excerpt from Kayes, Christopher-Kayes & Kolb, 2005)

> **Diverging**. The diverging style's dominant learning abilities are concrete experience and reflective observation. People with this learning style are best at viewing concrete situations from many different points of view. The style is labelled "diverging" because it facilitates generation of ideas, such as a brainstorming session. People with a diverging learning style like to gather information. Research shows that they are interested in people, tend to be imaginative and emotional, have broad cultural interests, and tend to specialize in the arts. In formal learning situations, people with the diverging style prefer to work in groups, listening with an open mind and receiving personalized feedback.
>
> **Assimilating**. The assimilating style's dominant learning abilities are abstract conceptualization and reflective observation. People with this learning style are best at understanding a wide range of information and putting it into concise, logical form. Individuals with an assimilating style are less focused on people and more interested in ideas and abstract concepts. Generally, people with this style find it more important that a theory have logical soundness than practical value. The assimilating learning style is important for effectiveness in information and science careers. In formal learning situations, people with this style prefer readings, lectures, exploring analytical models, and having time to think things through.
>
> **Converging**. The converging style's dominant learning abilities are abstract conceptualization and active experimentation. People with this learning style are best at finding practical uses for ideas and theories. Individuals with a converging learning style prefer to deal with technical tasks and problems rather than with social and interpersonal issues. These learning skills are important for effectiveness in specialist and technology careers. In formal learning situations, people with this style prefer to experiment with new ideas, simulations, laboratory assignments, and practical applications.

Accommodating. The accommodating style's dominant learning abilities are concrete experience and active experimentation. People with this learning style learn primarily from "hands-on" experience. They enjoy carrying out plans and involving themselves in new and challenging experiences. They tend to act on "gut" feelings rather than on logical analysis. In solving problems, individuals with an accommodating learning style rely on people for information more than on their own technical analysis. This learning style is important for effectiveness in action-oriented careers such as marketing or sales. In formal learning situations, people with the accommodating learning style prefer to work with others to get assignments done, to set goals, to do field work, and to test different approaches to completing a project.

Kolb discussed the learning style preference as the product of two pairs of variables, presented as lines of axis resulting in conflict mode each: i) Concrete Experience (feeling) vs Abstract Conceptualization (thinking), ii) Active Experimentation (doing) vs Reflective Observation (watching). Learning styles may be presented in a two-by-two matrix (Table 3).

Table 3: Kolb's learning styles; drawn from: Kayes, Christopher-Kayes & Kolb, 2005.

Kolb's learning styles	Active Experimentation – AE (doing)	Reflective Observation – RO (watching)
Concrete Experience - CE (feeling)	accommodating (CE/AE)	diverging (CE/RO)
(Abstract Conceptualization - AC (thinking)	converging (AC/AE)	assimilating (AC/RO)

Regarding the simulated situation within an experiential cycle (such as Figure 12: Kolb's Experiential Learning Theory model (ELT model); source: Kayes, Christopher-Kayes & Kolb, 2005.Figure 12, Kolb's ELT model), Beguin & Pastré (2002) pointed out that it is important not to be fixed on the one of the two possible aspects of simulation during its conception, use or analysis: the figurative aspect or the operative aspect (with the meaning of Pastré, 2005 defined below) referring to a "reference situation", where "reference situation" is an ideal operating situation designed from a set of real operating situations close to each other. Focusing on the figurative aspect would deal with the workers' activity. Focusing on the operative aspect would consist of only taking care as closely as possible of the respect of the physical, technical and organizational characteristics of the reference situation. Considering both aspects together, Pastré (2005) demonstrated that the simulator appeared as an artifact that simulates the operation or the behaviour of a technical system or a natural phenomenon, therefore a mediator between the trainees and the context. This finding is of importance in order to clarify the function of the simulator in the experiential cycle and the function of the simulator inside the simulated situation. Samurçay & Rogalski (1998) suggested that the simulated situation be thought of as a mediator for the activity development in a real operating situation. They advocated that in simulation training, the question was therefore that of mediations: mediation by the trainer, by the simulator artifact, and also by the simulated situation as well as by the reference situation.

These considerations suggest adapting Kolb's EL model for training integrating Samurçay & Rogalski's model which has not yet been done and no model is available in the literature to take such an approach into account. The aim is here to obtain an improved level of description of simulation training through a refined modelisation using a unique adapted model that might contribute to better understanding of how to create efficient mobilisable competencies for work activities. In addition, this approach must be considered within a complex socio-technical system: this implies taking into account relationships between real operating situations and simulated situations (via the reference situation) but also between the industrial organization (providing the real operating situation) and the training centre (elaborating the simulated situation) as well as between their constitutive elements and the associated interactions. Again, no model focusing on training in complex socio-technical systems is available in the literature developing such an approach.

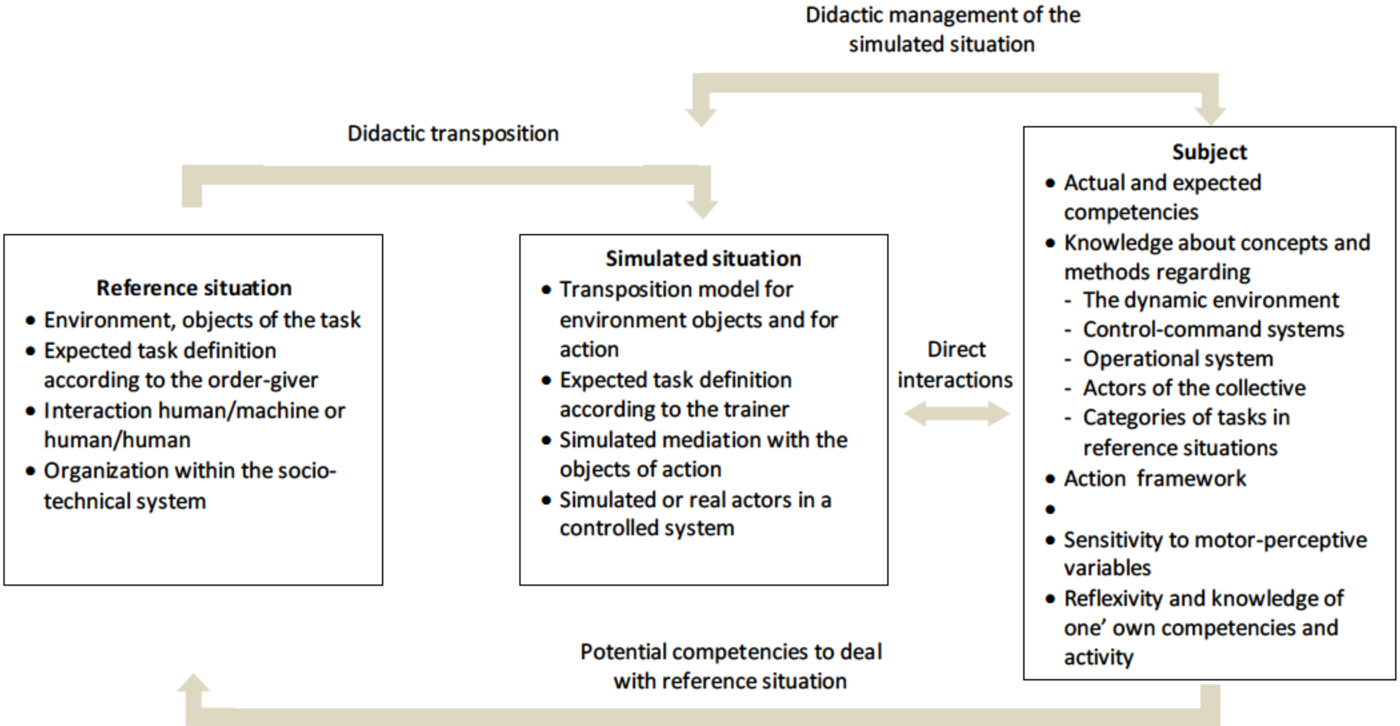


Figure 13: Model of the mediation in simulation adapted from Samurçay & Rogalski (1998).

These findings lead to a second research question:
RQ2: How are 'mobilisable competencies' elaborated through training in high risk industries?

From the outset, this research question integrates the fact that complex socio-technical systems usually improve occupational training for operational professions (more than 60% of the staff of a nuclear plant) through High Fidelity full-scale simulations as exposed in section I-1. This implies that RQ2 integrates this factor despite not being explicit in its formulation.

Another implicit factor is the collaborative dimension of the work activity in high risk industries. This aspect needs a dedicated analysis as done in the next section.

II-4-3 The collaborative dimension

II-4-3-a Collaboration, cooperation, competition

The literature review undertaken on this topic showed that the definition of collaborative activity, mutual activity, collaborative work, or collaboration was often not clearly defined by researchers studying this concept, as noticed by others (see for example: Omicini & Ossowski, 2004). It seemed as if there was a tacit agreement and understanding of what was collaborative or mutual activity.

The Cambridge dictionary suggests that "collaborative working" is "the act of two or more people or organizations working together for a particular purpose" and that "mutual" is "held in common by two or more parties". From these definitions we extend that collaborative activity is working together (in Latin: *cum laborare*: with/together work) towards mutual goal(s). Collaborative activity involves/implies task interdependency. It may concern different levels, such subjects or institutions, through subjects (see for example Kaiser (2011) for interagency collaborative activities).

Some authors oppose "collaborative activity" to "cooperative activity" according to the social level symmetry of the co-workers. If we refer to the definition given by Gillespie & Richardson (2011: 609), "cooperative activity is defined by having a division of labour such that participants have different social positions and experience different situational demands. [...] successful completion of a cooperative activity entails participants cooperating across their differences. Collaborative activities, in contrast, are defined as activities where people work together without differentiated roles or responsibilities."

However most of the authors do not oppose collaboration and cooperation. This is the case for Bratman (1992): collaboration may be cooperation (in Latin: *cum operare*: with/together operate) but collaboration is not systematically cooperation: competition (in Latin: *cum competere*: with/against compete) is also a form of collaboration. The oxford dictionary states that competition is an "activity or condition of striving to gain or win something by defeating or establishing superiority over others". Deutsch (1949, 1962) differentiated cooperative situation from competitive situation by the relationships existing between the individuals' goals linked together through a positive (resp. negative) correlation between their goal attainments (Johnson & Johnson, 1974). For Bratman as for others (Clark, 1996; Deutsch, 2000; Klein et al., 2004), collaboration is a joint activity carried out by subjects who intend to work together. According to Bratman (1992: 328), collaboration becomes cooperation when there is mutual responsiveness between co-workers (A needs B and B wants to respond and vice versa) and commitment to mutual support (A needs B and B can respond and vice versa) in addition to the commitment to the joint activity (statement of intent to work together). This differentiation between cooperation and competition in collaboration was recently illustrated through an interesting experiment exemplifying different aspects of collaboration. This was undertaken by Professor Alexandrov's team (Apanovitch et al., 2016a). Pairs of subjects (N=78) were presented with a simple decision-making task: pressing a button when detecting a single visual stimulus, both subjects having in front of them a button. This task was performed in several modes: Participants solved the task in three different social interaction conditions: 1) collaboration and no interaction with others, 2) competition with others, and 3) cooperation with others (Apanovitch et al., 2016b). The "no interaction" mode consisted in asking one subject to act while the other was watching. The competition mode required the subjects to press their button before the other when the stimulus appeared. In cooperation mode, one of the subjects was designated to press the button as soon as possible and before the other. The results revealed differences in the behavioural and EEG characteristics correlated to the cognitive style and they objectified a clear differentiation between conditions 2 and 3 from a neuroscience angle.

Most of the authors adopted the Activity Theory approach for collaborative activity analysis. Bardram (1998) included cooperation as a form of collaborative activity and pointed out that "Activity Theory describes cooperation as a collaborative activity with one objective, but distributed onto several actors, each performing one or more actions according to the overall and shared objective of the work." He re-discussed the proposal of Engeström et al. (1997) who suggested a three-level structure of a collaborative activity: co-ordinated, co-operative, and co-constructive collaborative activity; the levels are defined of as follows (Engeström et al., 1997; Bardram, 1998; Omicini & Ossowski, 2004: 3):

> *The co-ordinated aspect* of work captures the normal and routine flow of interaction. Participants follow their scripted roles, each focusing on the successful performance of their actions, either implicitly or explicitly assigned to them; they share and act upon a common object, but are not necessarily aware of this fact. The scripts coordinating participants' actions are not questioned or discussed, and need not be known and understood in all their complexity: in this stage, actors act as 'wheels in the organizational machinery' and co-ordination ensures that an activity is working in harmony with surrounding activities.
> *The co-operative aspect* of work concerns the mode of interactions in which actors focus on a common object and thus share the objective of the activity; unlike previous cases, actors do not have scripts, actions or roles explicitly assigned to them: with regard to the common object, each actor has to balance his/her own actions with other agent actions, possibly influencing them to achieve the common task. So, co-operative activities assume that the object of the activity is stable and agreed upon, but the means for achieving the goal is to be defined and forged at this level.
> *The co-constructive aspect* of work concerns interactions in which actors focus on re-conceptualizing their own organization and interaction in relation to their shared objects. Neither the object of work,

nor the means to achieve them are stable, so that they should be collectively constructed, i.e. co-constructed.

The authors emphasized that the co-ordinated level is characterized by stable means of work ("Such means are primarily the script revealing a distribution of the activity into several actions and actors, and the mediating artefacts", Bardram, 1998: 91), the co-operative level is characterized by stable object of work (it does not address one object then another; the object does not change even though it is transformed throughout the activity) and the co-constructive level is characterized by non-stable means and a non-stable object of work. Moving from one level to another implies stabilization or a reflection (destabilization) about means or object. Bardram (1998) warned that these three levels were "analytical distinctions of the same collaborative activity" but "an activity cannot be said to exist on one level alone" (p.92). Similarly, Deutsch pointed out the interlaced nature of these levels by categorizing communication and coordination as positive characteristics of cooperative relationships. He also pointed out that this three-level structure excluded de facto the competitive form of collaboration otherwise it should take into account at least obstructed communication and inability to coordinate activities.
"Means" and "object of work" suppose that they are included in and supported by an organizational system that provides shared rules or ways of practices: Heath & Luff (1991: 67) suggested that "collaboration necessitates a publicly available set of practices and reasoning which are developed and warranted within a particular setting, and which systematically inform the work and interaction of various personnel" among which the way to communicate (Engeström et al., 1997; Bardram, 1998; Omicini & Ossowski, 2004).

Collaboration may also be considered in terms of common goals and motives (Lahlou et al., 2004). The common goal is the conscious representation of the future result which a group of individuals tries to reach. The group of individuals can then act as a "collective subject". The representation is mental, thus in the mind, but the mind of the collective subject is distributed over the individuals' minds. As a consequence, the mutual goal exists on the condition that the individual representations match a given representation, which must be shared: the mutual representation. "The study of joint activity must show how the members of the group take ownership of a mutual goal, and in turn in which form each individual takes ownership of it [this mutual goal] (Lomov, 1984; Nosulenko & Samoylenko, 2009). To achieve a mutual goal, each participant must indeed identify it also as a personal goal" (Nosulenko & Samoylenko, 2011: 663). There is therefore a mutual/common/collaborative activity integrating individual activities, each of them being performed according to individual goals but also according to mutual goals for which communication has an essential contribution (Lomov, 1984).

Collaboration may also be considered in terms of action feedback. Deutsch (2011) underlined a possible (a)symmetric relationship between individuals involved in competitive activities depending on the effect possibly produced on the challengers: "suppose that what you do or what happens to you may have a considerable effect on me, but what I do or what happens to me may have little impact on you. I am more dependent on you than you are on me" (p.25). Fauquet (2006), observing work activities in nuclear reactor control rooms, noticed that the action feedback might be immediate or deferral depending on the work context. Both authors pointed out the resulting influence on co-workers behaviours and on the performance of the activity.

In addition, as highlighted by several other researchers (see for example Luff, Heath & Greatbatch, 1992; Lahlou, Nosulenko & Samoylenko, 2012), analyses of collaborative activities must deal with both types of activities within the collaborative activity: individual and joint. However, this first approach needs precision: the individual activity being a component of the collective activity, the relative position of each actor must be clarified as well as the functional position of each worker with regard to the co-worker. Their activities are temporally dependent to each other and are "synchronous" (Le Bellu, 2011), jointed in time. The opposite phenomenon was also pointed out in terms of “asynchronous” by Luff, Heath, & Greatbatch (1992), possibly characterized by the “asynchronous nature of participants’ actions” (Ellis & Gibbs, 1989: 400).

The criteria characterizing collaborative activity elaborated from the literature review (excluding competitive form of collaboration as we shall not address this form of collaboration in the present study) are listed in Table 4 (left column) with the associated sources (middle column). Criteria are mandatory properties for the activity to be collaborative or cooperative. Then, activities may have facultative properties according to what was reported in the literature review. The properties are listed in Table 5.

In practice, in complex settings such as nuclear industry, collaborative activities are often nested in a multi-tasking context. They verify properties pointed out by Rogers & Ellis (1994): collaborative activities “are fragmented by virtue of both their interwoven nature and the fact that they are situated within an intricate network of social interactions.” This has an impact on the performance of collaborative activities depending on the form of the collaboration: in the domain of motor performance, it was found that cooperation led to higher performance than competitive or individual conditions (Johnson et al., 1981; Stanne et al., 1999; Peng & Hsieh, 2012; Plass et al., 2013). Similarly, Bardram (1998: 89) wrote that “when cooperation breaks down, changes over time” it may be “perceived differently by different actors involved” (p.89); to illustrate it, Bardram referred to Bødker & Mogensen (1993) “when they, based on an analysis of the cooperation between a labour inspection officer and his secretary, conclude that ‘one woman’s job is another man’s articulation work’ – i.e. that the same work from one perspective is viewed as coordination of the ‘real work’, and from another perspective is viewed as the work per se” (p.90). These remarks question the criteria given in Table 4 describing characteristics of collaborative activity: if subjects’ perspective-taking are opposed (e.g. subject A thinks subject B is involved in cooperation but subject B thinks subject A is not involved in cooperation) how do they elaborate the criteria “Subjects share the general mutual goal related to this task” and “Subjects coordinate their actions”? Moreover, since taking an opposed perspective might compromise the effectiveness of cooperation, we may assume that it has an impact on the efficiency of the activity when designed and thus expected to be cooperative by the organization: it deteriorates the mutual representation of the aforementioned collective subject (Lahlou et al., 2004). However, et al. (2012) showed that perspective-taking could increase collaborative performance when co-workers are engaged in perspective-taking conversely to the case where they are not instructed to take their team members’ perspectives. For Klein et al. (2004), perspective-taking between co-workers relates to a “common ground” that includes beliefs and assumptions which are shared among the co-workers contributing to provide an interpredictability of co-workers’ attitudes and actions. According to these authors, this interpredictability is a key factor in enhancing coordination performance and might be based on a shared mutual representation. Bratman (1998: 338) qualified perspective-taking as an essential attitude to cooperation. It would thus be valuable to assess the effectiveness of appropriate perspective-taking between co-workers. For this aim, the use of the Intersubjective Theory might be of great help.

Table 4: Criteria describing collaborative activities elaborated from the literature review.

Criteria	Examples of scientific sources	collaborative	cooperative	co-constructive	competitive
Several subjects are involved.	General definition, Oxford dictionary Deutsch (1949, 1962) Johnson & Johnson (1974) Bratman (1992)	x	x	x	x
Subjects are related by organizational relations.	Heath & Luff (1991)	x	x	x	x
Subjects are related by timelines (defined by beginning and end).	Heath & Luff (1991) Deutsch (1949, 1962) Johnson & Johnson (1974)	x	x	x	x
Subjects share the general mutual goal related to this task	Deutsch (1949, 1962) Johnson & Johnson (1974) Lomov (1984) Nosulenko & Samolienko (2009, 2011) Lahlou et al. (2014)	x	x	x	x
positive correlation between the individuals' goals	Deutsch (1949, 1962) Johnson & Johnson (1974)	x	x	x	
negative correlation between the individuals' goals	Deutsch (1949, 1962) Johnson & Johnson (1974)				x
subjects aim at performing together the same task (commitment to the joint activity)	General definition, Oxford dictionary Deutsch (1949, 1962) Johnson & Johnson (1974) Bratman (1992) Clark (1996) Bardram (1998) Engeström et al. (1997) Deutsch (2000) Omicini & Ossowski (2004) Klein et al. (2004)	x	x	x	x
mutual responsiveness (A needs B and B wants to respond and vice versa)	Bratman (1992)	x	x		
commitment to mutual support (A needs B and B can respond and vice versa)	Bratman (1992)	x	x		
Subjects coordinate their actions	Bratman (1992) Bardram (1998) Engeström et al. (1997) Omicini & Ossowski (2004)		x	x	
Subjects communicate	Lomov (1984) Bardram 1998 Engeström et al. (1997) Omicini & Ossowski (2004)	x	x	x	/
Means are stable	Bardram (1998) Engeström et al. (1997) Omicini & Ossowski (2004)		if coordinated		/
Object of work is stable	Bardram (1998) Engeström et al. (1997) Omicini & Ossowski (2004)		x		/
A system providing the organizational relations can be identified	Heath & Luff (1991)	x	x	x	x
Subjects act within this system	Heath & Luff (1991)	x	x	x	x

Table 5: Properties characterizing collaborative activities elaborated from the literature review.

Identified properties	Examples of scientific sources
Subordinate type (organizational aspect)	Gillespie & Richardson (2011)
Subordinate type (factual aspect)	Gillespie & Richardson (2011)
(A)synchronous real time	Le Bellu (2011) Luff, Heath, & Greatbatch (1992) Ellis & Gibbs (1989)
Task-load (a)symmetry	Le Bellu (2011)
Disturbance (a)symmetry	Rogers & Ellis (1994) Fauquet (2006)
Remote/Nearby activity	Luff, Heath, & Greatbatch (1992) Fauquet (2006)
Actions feedback immediate/deferral	Fauquet (2006)
Actions feedback (a)symmetry	Deutsch (2011)

II-4-3-b Intersubjectivity

According to Rommetveit (1974), intersubjectivity, may be understood as One's orientation to the orientation of Other. In the line of Mead (1912, 1913) suggesting this reflection as part of intersubjectivity, it may be understood through a perspective-taking approach. Ichheiser (1943) proposed a three interactional-level approach: the individual/group self-perception, the individual/group perception of Other, the perception of individual/group of the Other's perception of themselves. More recently, Gillespie (2007: 275) emphasized that these three levels may be considered to operate at two levels from the interlocutors' standpoint: "First, there is the level of a person's direct perception of Self or Other, and second there is the level of perception of the perspective of Other" which helps "to conceptualize how someone or a group might try to appear trustworthy. To appear trustworthy, they must orient to the criteria that they think Other is using in order to determine trustworthiness". The first level was conceptualized as the "direct perspective" by Laing et al. (1966), the second as "meta perspective", and the authors added as a logical possibility a third level, the meta-meta-perspective: the perception of individual/group of the Other's perception of their perception of themselves. On the basis of Laing and co-workers' studies, Gillespie (2007: 276) reformulated how these three levels of perspectives could be important and illustrated it by referring to the Cold War analysed by the authors who argued that "the distrust between East and West operated at each of their three levels. Not only did East and West fear each other (direct perspectives), but they were each aware that the other feared them (meta-perspectives), and they each knew that the other was aware that they knew the other feared them (meta-meta-perspectives)." Gillespie (2007) thus suggested a model of intersubjective structure of trust and distrust articulated upon these three levels and pointed out that a context of trust or distrust was satisfied when the three levels were fulfilled according to this structure through intertwined properties as described hereafter. The intersubjective structure of trust and distrust was recently tested and validated when applied to the communicational process of food marketing by Fauquet-Alekhine & Fauquet-Alekhine-Pavlovskaia (2016c) and the present analysis about intersubjectivity is excerpted from their article.

The entwined properties characterizing the intersubjective structure of trust and distrust may be easily depicted on a diagram. Let us consider two individuals involved in an intersubjective process; we call them "interactants". The two interactants are Self (S) and Other (O). The direct perspective (DP) assumes that S assigns an attribute (A) to O and vice versa. DP gives two statements. Statement (S)1="S thinks A about O" and Statement (O)1="O thinks A about S". The meta perspective (MP) considers that each of them knows these statements. Again MP yields two statements: Statement (S)2="S knows Statement (O)1" and Statement (O)2="O knows Statement (S)1". This means that "S knows O thinks A about S" and Statement (O)2="O knows S thinks A about O". Finally, the meta meta perspective (MMP) addresses an upper level of knowledge. MMP produces two statements: Statement (S)3="S knows Statement (O)2" and Statement (O)3="O knows Statement (S)2". The relationships drawn on Figure 14, when complying with the intersubjective structure as described here, give a strong consistency to the context. The way properties are entwined on Figure 14 implies that the relationships between S and O are bilateral and analogous.

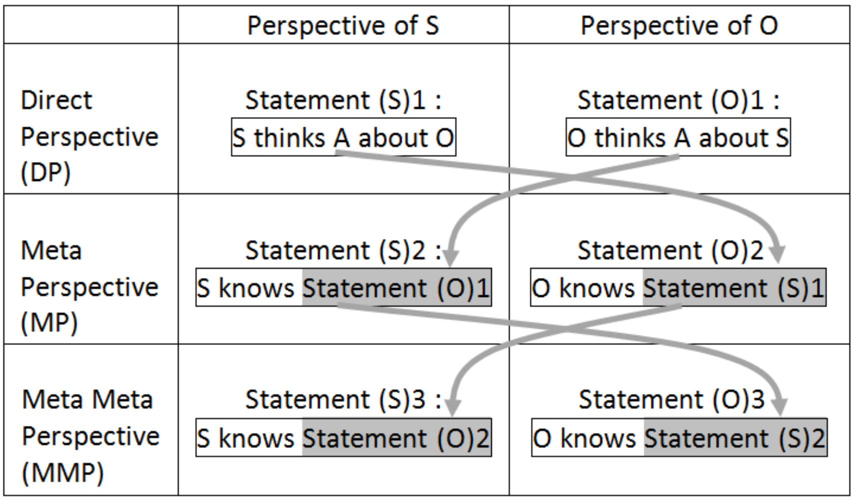


Figure 14: The intersubjective structure of trust and distrust between Self (S) and Other (O) each of them assigning to each other the same attribute (A)

When applied to collaborative activity, the intersubjective structure may be thought of in terms of collaboration rather than trust. The expression of the intersubjective structure of collaboration is then as follows: DP gives two statements. Statement (S)1="S thinks O works with him" and Statement (O)1="O thinks S works with him". MP yields two statements: Statement (S)2="S thinks Statement (O)1" and Statement (O)2="O knows Statement (S)1" and MMP produces two statements: Statement (S)3="S knows Statement (O)2" and Statement (O)3="O knows Statement (S)2". In other words, when S thinks that O works with him, knows that O thinks S works with O and knows that O knows S works with O, and vice versa (the same inverting S and O) then there is a coherent perspective taking within an intersubjective structure of collaboration that might contribute to the efficiency of the cooperative dimension of the activity: this is made possible when the following criteria are effective (from Table 4) "Subjects share the general mutual goal related to this task" and "Subjects coordinate their actions". This is why it might be of great interest to assess the intersubjective structure during collaborative activity and analyse the correlation with the activity performance.

To summarize section II-4, concerns regarding simulation training design were addressed. Several models were considered, especially these of Samurçay & Rogalski (1998) and of Kolb (1976, 1984), each explaining different parts of simulation for occupational training. It led to (RQ2): How are 'mobilizable competencies' elaborated through training in high risk industries?. In addition, when considering the unavoidable collaborative dimension of work activities in high risk industries, thus to be taken into account during simulation training, it was emphasized the potential relevancy of Intersubjectivity Theory.

Chapter III - Materials & Methods

For each research question (RQ), Chapter III presents and argues the method adopted with the aim of answering it.
Section III-1 "Accessing competencies of experienced workers" addresses (RQ1) "How are competencies of experienced workers mobilized and how to access them?" It structures an assessment of the synthetic and consensual model for knowledge, know-how (KKHS) and skills under the general concept of competencies that was suggested from the literature review. It structures an assessment of Le Boterf's model for competencies in action with regards to present research needs. It helps us to understand what the exploratory focus must be so as to answer RQ1 and it frames a protocol based on Lahlou's early work to access what makes workers' competencies. It then presents the related empirical material (activities, context and workers). Two phases are planned: an experimental test segment undertaken in simulated situations and an applicative test segment carried out in real operating situations. Both address work activities on a nuclear power plant and both aim at providing relevant input data for occupational training through simulation.
Section III-2 "Elaborating and applying competencies in high risk industries" addresses (RQ2) "How are 'mobilizable competencies' elaborated through training in high risk industries?" It aims at applying results that will provide the experimental and applicative test segments in simulation training. It explains how field experiments are chosen and negotiated. Then the material is presented. Four different complex sociotechnical systems were identified amongst which two fell through during the negotiation phase (EDF Energy (UK) and French Air Force). The others (EDF SA and University Hospital of Angers, both in France) offer four different field experiments. The way in which the needs of the sociotechnical systems meet the objectives of the present research and the methods envisaged to reach the goals are described.
A final section addresses ethical concerns.

Most of the field experiments were carried out at Chinon NPP through a sponsoring partnership: as a matter of fact, the sponsor had engaged the present research in order to identify and understand strengths and weaknesses in the professionalization cycle of Operations teams trained on simulators and was expecting suggestions of areas for improvement. Therefore it was mandatory to select as field experiments those activities for which the sponsor needed performance improvement. The main expectations concerned the application of reliability practices and the circuit configurations. These will be described further. However, the findings could not be generalized without exploring other complex socio-technical systems. Therefore, other field experiments were considered.

In this chapter, Methods & Materials are discussed first for RQ1, then for RQ2.

III-1 Accessing competencies of experienced workers

This is to answer **RQ1**: How are competencies of experienced workers mobilized and how can they be accessed?

III-1-1 Method for accessing competencies of experienced workers

We first tested the operational validity KKHS synthesis for Knowledge, Know-How and Skills (Figure 4) resulting from the literature. This was to ensure that the option chosen for this synthesis was relevant. Then, before integrating Le Boterf's model into the method, a pre-test was necessary as no experiment was available to validate the assumption that mobilization of competencies through three poles, *Knowing (how) to act, Wanting to act, Being able to act* was correctly and sufficiently described. Finally the model had to be combined with the adapted SEBE method of Le Bellu and the resulting protocol had to be tested.

III-1-1-a Testing the KKHS synthesis for Knowledge, Know-How and Skills

The operational validity of KKHS synthesis for Knowledge, Know-How and Skills was tested by confronting workers' perceptions when putting their competencies in action for one of their work activities (N=50, different profession, different position). Subjects were individually contacted to assess statement S1 and answer questions Q1 and Q2[8]:

S1 In your opinion, you are skilled in this activity (Likert scale (coded from –2 to +2))

Q1 In your opinion, what is firstly required in terms of competencies for a novice who will perform this activity?

Q2 In your opinion, when performing this activity, do repetition or frequency most improve your skills?

S1 was a filtering statement in accepting or rejecting the subjects' contribution: as subjects were expected to describe their knowledge, know-how or skills, if they did not feel skilled in the activity they described, we might assume that it would be difficult for them to talk about their skills and thus create a bias in the data; these subjects would be rejected.

Q1 and Q2 were elaborated from the literature review with the objective of testing the operational validity of the synthesis. Q1 was assumed to contribute to discriminate knowledge, know-how and skills and what was first required among them in a learning process. Q2 was formed so as to test the validity of the two dimensions of the synthesis, the rate-X-axis and the number-Y-axis on Figure 4.

Socio-demographic data was also collected. Data was used after statistical analysis.

III-1-1-b Testing Le Boterf's model for competencies in action

The literature review showed that Le Boterf's model (1998) was the one which presented the closest link between competencies and action. The three poles of the model Figure 9 were considered in order to describe activities by workers. The details collected through interviews were then attributed to the model poles as far as was possible. For this data collection, the same persons contacted for testing the KKSH synthesis (N=50, different profession and different position) where individually asked to describe an activity requiring their professional competencies. During these individual interviews, the researcher was looking for elements relating to each part of Le Boterf's model (acceptation of the model) as well as looking for elements that would be required for competencies in action but not described by the model (rejection of the model). At this stage, a full description of the activity was not needed: the objective of the interview was to attain details that fitted the poles and to focus on details that were not described by the poles. The assumption was that characterization of the non-attributed details, should it exist, could help to adapt Le Boterf's model for the present research.

Following this pre-test, Le Boterf's model was tested in an attempt to fully describe competencies in action for subjects (among subjects contacted for the pre-test). For this aim, subjects were individually contacted to participate in an interview the aim of which being to describe in detail one of their activities. Subjects were selected according to their profession which had to comply with three criteria:

- Subjects had different professions and different positions in order to provide different testing cases.
- Each profession had to involve at least ten different people (hereinafter the professional collective), all of them having the same position and similar missions so that the collected material could maintain their anonymity.
- In each case, the activity chosen for the description had to be part of the set of common missions of the profession shared by each member of the professional collective again for reasons of anonymity.

These considerations led to selecting N=3 different professionals i.e. 3 subjects each having a different profession.

[8] In French, original questions were:
S1: Selon vous, vous êtes compétent pour cette activité.
Q1: Selon vous, qu'est-ce qui est d'abord requis pour un novice en termes de compétences pour réaliser cette activité ?
Q2: Selon vous, réalisant cette activité, qu'est-ce qui améliore votre compétence entre la répétition et la fréquence ?

The description was obtained through a semi-structured interview with two main questions, one already used for RQ1, Q1, and a new question Q3[9] opening the scope of investigation of Q1:
Q1: In your opinion, what is firstly required in terms of competencies for a novice who will perform this activity?
Q3: In your opinion, what makes you put your competencies in action for this activity and makes you perform it successfully?

The assessment of the model relied on its capacity to take everything the subjects had described into account, a suitable model being expected to be able to take account of the entirety.

Although Le Boterf's model was selected as the more suitable, the same exercise was then carried out with other models identified in the literature review (section III-2) in order to assess and compare their capacity to take the description of the activity into account and compare their performance with that of Le Boterf.

If satisfactory (being able to take the whole description into account or at least as much as possible and in a better way than other models), Le Boterf's model was then assumed to be suitable to help us to design a protocol aiming at understanding how competencies are mobilized in work activities (part of RQ1). This is presented in the next section.

III-1-1-c Adapting Le Bellu's SEBE method integrating Le Boterf's model - Testing

As a conclusion of the literature review, the expected protocol was based on the adaptation of Le Bellu's work (2010, 2011) who applied a SEBE/PQT protocol. This implied that the general structure of the expected protocol was at least:

- capturing the work activity by a sub-cam with video recording,
- analysing the resulting video through replay interview.

Comparing Le Bellu's choices and the present research needs, a refined protocol was adapted. These adaptations were:

- to reduce the size and weight of the SEBE equipment in order to make it more easily accepted by subjects and easily carried into ROS (especially in industrial fields),
- to access explicit as well as tacit competencies, implying favouring the naturalistic character of activities as suggested by Polanyi (1967) and by Nonaka & Takeushi (1995) on the contrary of Le Bellu who worked with controlled situations,
- to access both individual and collective competencies while Le Bellu explored only individual competencies,
- to take into account the collaborative dimension of the collective activity, not done by Le Bellu as she explored only individual technical gestures.

Then, the resulting protocol had to be tested. This was carried out in two phases named "experimental test segment in SimS (Simulated Situations)" and "applicative test segment in ROS (Real Operating Situations)". The experimental test segment was to calibrate the protocol. The applicative test segment was to test the possibility of application in daily operating conditions.

During the experimental test segment, several factors were examined:

- factors regarding the capacity (implementation, capture, data relevancy; see below) of the protocol,
- factors regarding the performance of the protocol through comparison with other methods,

[9] In French the original question was:
Q3 : Selon vous, qu'est-ce qui fait que vous mettez en œuvre vos compétences en action pour cette activité et que vous parvenez à sa réalisation avec succès ?

- factors regarding the capacity of the PhD researcher to conduct the replay interview.

These factors and the associated test method are described further on.

Testing the protocol capacity was undertaken through a factual assessment according to criteria for:

- being easily implemented.
- capturing relevant data with regards to RQ1.
- providing relevant conclusions after analysis of the data with regards to RQ1.

These criteria are denoted by "ICC criteria" hereafter for "Implementation, Capture and Conclusion".

Testing the protocol through comparison with other methods was undertaken in work activities. These work activities were jointly selected with the sponsor (see section III-1-2). The other methods used for comparison were known to provide data with the same objective (describing what the competencies of the experienced workers are). The results obtained, applying each method, were compared with the results obtained applying the protocol in order to assess their relative performance in terms of Relevancy, Completeness and Efficiency (denoted by hereafter "RCE criteria"). Evaluation of relevancy and completeness was undertaken by comparing the number of knowledge and know-how items (explicit, tacit, individual and collective) provided by each method per activity; evaluation of efficiency was assessed by comparing the time spent to obtain the results and the related cost (man-day).

The other methods known and applied in the company to provide data with the same objective were the SAT method within the framework of an action program named "Competencies Program", the SAT method combined with a description-based method and the Self-confrontation. They are described in section II-3-3.

When comparing the protocol with the self-confrontation, the replay interviews were carried out for two activity cases in order to compare the performance of the methods with regard to the final goal: having access to mobilized competencies of the worker. The two cases were similar activities (in terms of objects of work and for work, content, complexity, duration) in the same context and performed by the same worker. They helped the evaluation to reduce the bias which could be due to the primacy effect possibly resulting in a second better structured replay interview than the first one and therefore ensuing in a higher performance of the second applied method. In cases 1 and 2, methods were applied the other way round. We propose that if the proof of a higher performance of one of the method was significantly done for one activity (individual or collective), the result might be generalized.

When comparing the protocol with the SAT method, there could not be consequences due to the primacy effect (described just above) as the SAT results were provided by the company database from analyses undertaken in other plants of EDF SA nuclear fleet.

When comparing the protocol with the SAT-Description-based method, there could not be consequences due to the primacy effect for the same reasons.

During the applicative test segment, activities were analysed applying the developed protocol based on Le Boterf's model and results regarding mobilized competencies of workers were compared with the results provided by the SAT; as a tool applied in the professionalization organization of the company, the SAT method was common to all the ROS studied. This allowed us to gain access to the RCE criteria for $N_{act/app}$ different activities (see Table 10).

The test strategy is summarized on Figure 15 for the two test segments.

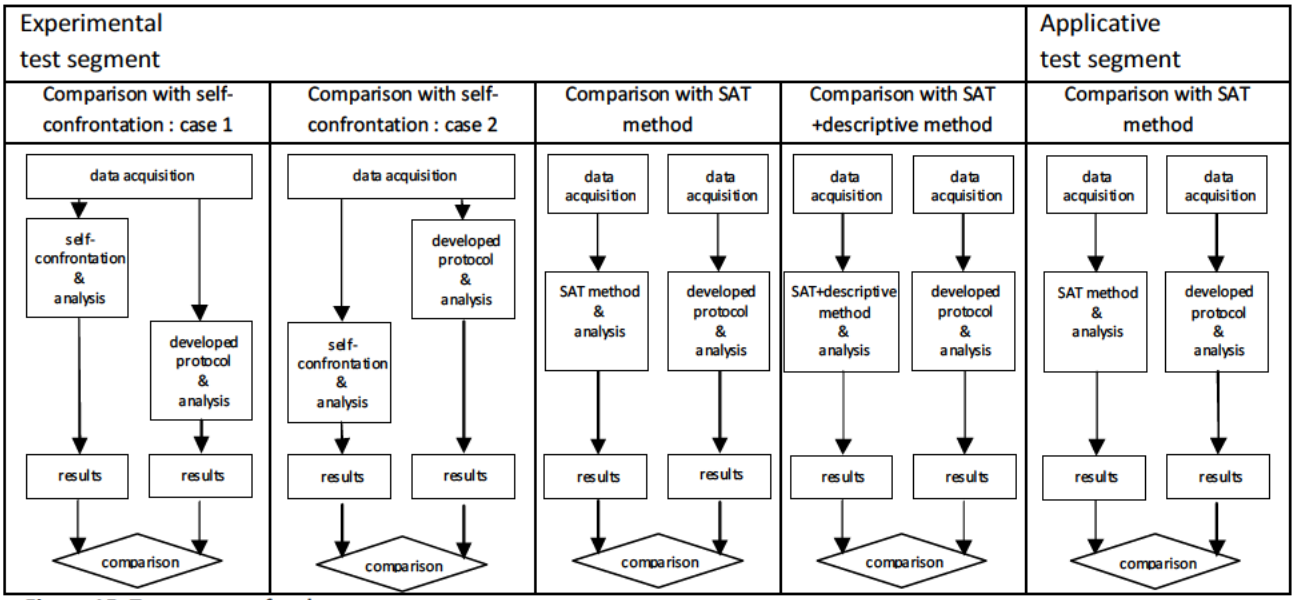


Figure 15: Test strategy for the two test segments.

Assessing the analyst's performance

During the experimental test segment undertaken in SimS (Simulated Situation), the factor regarding the capacity of the PhD researcher to conduct a replay interview as required by the protocol was assessed by qualified experts. This was decided so as to avoid or prevent alteration of the performance of the protocol due to a lack of competencies of the interviewer (the PhD researcher). For this aim, two qualified experts were asked to conduct replay interviews while the PhD researcher was observing, assess the PhD researcher's performance while he conducted replay interviews and finally provide advice. The experts' contribution corresponded to ICC criteria #C04 to #C30 (table C in appendix 1). The experts' contributions were provided separately in two SimS as reported in Table 8. The selected qualified experts were Professor Lahlou and Dr. Le Bellu (Dept. of Psychological & Behavioural Sc., LSE, London, UK) chosen for their high level of expertise in the field of work analysis using SEBE. However, rather than an assessment, these contributions were an adjustment phase as the PhD researcher had already elaborated competencies in conducting interviews for simulation training and work analysis in the past years as Human Factors Consultant at Chinon NPP.

Risk assessment protocol to avoid safety event

For industrial safety concerns, the experimental test segment in SimS had to demonstrate that the probability of the SEBE equipment (technical part of the method) causing issues was low enough for the protocol to be implemented in ROS. For this aim, a dedicated risk assessment protocol was designed and validated for different high risk professions before the applicative test segment in ROS. This work being a side aspect of the research, details are not given in this dissertation. However, they are available in two papers (Fauquet-Alekhine, 2014a; Fauquet-Alekhine et al., 2017b), the first paper being attached in appendix 7.

Summarizing the test

To summarize, the developed protocol based on Le Boterf's model was tested on the following points:

- The capacity to produce data through "Implementation, Capture and Conclusion" (ICC criteria) (undertaken in SimS).
- The comparison with other methods involving an assessment of Relevancy, Completeness and Efficiency (RCE criteria) (undertaken in SimS).
- The capacity of the PhD researcher to conduct a replay interview as required by the developed protocol involving qualified experts (undertaken in SimS).
- The possibility to provide a risk assessment protocol applicable to SEBE methods in high risk industries (undertaken in SimS and improved in ROS).

- The capacity to analyse collaborative activities (undertaken in SimS: the experimental test segment).
- The capacity to analyse individual and collective activities in daily operating conditions (undertaken in ROS: the applicative test segment).

Negotiations for field experiments

Obtaining the field experiments required negotiations for both SimS and ROS. To do so, several steps had to be respected so as to clarify the situation between all parties involved and in order not to frighten any of the managers or any other members of the teams: indeed, wearing a sub-cam to produce a video which would then be seen by a researcher, who would asked to speak about what he/she knows and does not know regarding a professional domain for which he/she is supposed to be skilful might be perceived as exposing by participants. The following steps were thus respected:

- Meeting the management of the department concerned by the chosen activity and presenting in details the innovative method, the experimental need and discussing the possible work activities concerned, then selecting the field experiment and elaborating the experimental plan, validating the experimental plan.
- Planning the experiments.
- Capturing the work activity by a subcam with video recording after obtaining informed consents signed by participants (see Ethics in section III-3).
- Analysing the resulting video through replay interview.
- Validating conclusions with participants.
- Sharing conclusions with participants and head management.

In addition, when beginning studies with the shift teams, it was agreed with workers and managers that the subjects involved in the experiments would be experienced and volunteers.

Two periods were investigated regarding the Operations shift team's activities: the end of 2015 and the beginning of 2016 was a period without outage of nuclear units, and deemed not to be overworked, and the second one following until the end of summer 2016 of high workload during unit outages. It must be noted here that, whilst undertaking analyses with shift teams during the first period, participants insisted on experiments being carried out during outages in order to observe how if might (not) work when the workload increased.

III-1-1-d The collaborative dimension

For both experimental and applicative test segments, collaborative activities were analysed in the light of the criteria and properties provided by the literature review and summarized in Table 4 and Table 5 Table 5 (section II-4-3-a). Criteria and properties were assessed through viewing the sub-films (what participants did) and through replay interviews (what participants explained about what they did) as effective or not: the assessment by the PhD researcher was coded 0 if not effective and 1 otherwise. The intersubjective structure of collaboration (section II-4-3-b) was also assessed. These factors were correlated with job performance. The assessment of the intersubjective structure of collaboration and job performance are described hereafter.

In order to assess the intersubjective structure of collaboration, the subjects' feelings and reasons for those feelings regarding the collaborative dimension, whilst viewing collaborative sequences of their subjective videos, were confronted and discussed. To do so, during these sequences, specific moments were selected for both co-workers which took place at the same time of day. For example, when 01:30am was visible on the field worker and the pilot's sub-film, subjects were asked about their perception of the collaborative dimension of their activity. This was done during their individual replay interview. These moments were selected during the preparation and debriefing phases of the activity, and also during the realization phase. For the latter, moments were selected when co-workers were communicating (face-to-face or by phone) or not and/or working directly with the co-worker (e.g. the field worker closed a valve because the pilot had just asked him to do it on the phone) or not (e.g. the field worker was walking in the machine room towards the valves he had to handle so as to carry out the collaborative activity).

These impressions were obtained from the four questions asked and then discussed with the subjects during individual interviews whilst viewing the associated video sequence:

- Did you get the impression you were working together at this moment?
- Did you get the impression you were working as a pair?
- Did you get the impression your colleague thought you were working together at this moment?
- Did you get the impression your colleague thought you were working as a pair?

These questions addressed the direct and meta perspectives of the subjects according to the Intersubjective Theory presented in section II-4-3-b. The meta-meta perspective was not questioned in order to avoid cognitive overload of the subjects:

- The first replay interviews showed that, after answering the two first questions, the subjects sometimes had difficulty understanding and answering the two questions that followed; this was not due to the subjects being limited intellectually but linked to the fact that they worked in shift teams: when you have to think about and answer these sorts of questions between 01 and 04am knowing your sleep pattern changes from one day or night to another and that you have been scrambling up and down and around the plant for several hours, it is clearly difficult to keep a clear mind when discussing concepts which you are not familiar with.
- The questions were repetitive: during one replay interview, the subject sometimes had to answer the same questions up to 8 times. Taking this point into account and also avoiding the subjects becoming bored, it was decided to avoid the meta-meta perspective; for example: Did you get the impression your colleague thought that you thought you were working together at that moment? Taking into account the fact that they would have also had to explain the answer, it was preferred to make them keep their energy to discuss and explain the SPEAC protocol questions.

The associated reasons were obtained from the two questions asked to and then discussed with the subjects:

- For what reasons did you (resp. your colleague) think you worked (did not work) together?
- What makes you feel this?

Then, among the analysed specifics moments, the proportion respecting the intersubjective structure of (non-)collaboration was calculated for each situation case. This proportion reflecting the subjects' coherence in terms of direct and meta perspectives, it was taken as an indicator of the way subjects had developed an efficient perspective-taking.

As for other criteria and properties, this proportion was associated with job performance through correlation calculation. This approach was crucial with the aim of identifying which factors led to a higher performance among those summoned in collaborative activities.

For the job performance assessment, we used a classical and simple scale commonly applied in the field of job performance assessment (see for example: Rynes et al., 2005; Helm et al. 2007; DCIPS, 2009; Smeets et al., 2013). This kind of scale presents the advantage to "be used for any type of job […] permit the assessor to factor in variables that are not under the employee's control but nevertheless influence performance […] allow a focus on whether results are achieved using acceptable means and behaviours […] generally carry less risk of measurement deficiency" (Rynes et al., 2005: 583; see also Wright et al., 1993; Arvey & Murphy 1998). Table 6 details these criteria and assigns for each a score between brackets.

Table 6: Criteria and scores for job performance assessment

criteria	Unacceptable (1)	Minimally Successful (2)	Successful (3)	Excellent (4)	Outstanding (5)
label	did not meet the expectations of the objective even though circumstances allowed for its achievement.	partially met the expectations of the objective; the result fell short of meeting the standards for quality, quantity, timeliness, and cost-effectiveness associated with the objective.	met fully with expectations of the objective; the result met the standards for quality, quantity, timeliness, and cost-effectiveness associated with the objective (e.g., met designated budget and/or timeframe) and was achieved with the appropriate level of guidance.	exceeded expectations of the objective; the results surpassed the standards for quality and quantity, and the timeframe associated with the objective (e.g., saved time or money).	greatly exceeded expectations of the objective; the result was exceptional and significantly surpassed the standards for quality, quantity, and timeframe associated with the objective (e.g., saved significant time or money)

Doing so, the job performance was easy to assess without the need for a dedicated assessment grid per activity or an expert to judge the job. However they remained approximate; the pre-test of this scale assessment applied to activities at Chinon NPP showed that it gave satisfactory discrimination of job performance.
Each of the domains addressed through the scale (quality, quantity, timeliness and cost-effectiveness) were easy to assess in ROS. The standards for quality were usually commented by the subject during the replay interview or during the activity debriefing. The standards for quantity were not related to a quantity of pieces to be produced but to the fact that the final goal of the activity could be reached. Again, this was naturally commented on by the subject during the replay interview or during the activity debriefing with their colleagues. The timeliness and the cost-effectiveness of the activity were easily rated when compared with the shift schedule for activities: the appropriateness between the schedule and the work done, corresponded to work done in time and without additional cost. This was discussed during shift briefing, during the activity debriefing or during the shift team debriefing.

For each of the domains addressed through the scale, a score was assigned respecting the aforementioned approach and a final score was given by calculating the average.

Job performance assessment was performed by the PhD researcher on based on the subfilms and replay interviews analyses. The PhD researcher' was considered competent to carry out this sort of assessment due to 4-years professional experience as an expert in safety followed by 10 years as a Human Factors Consultant, both in a French NPP.

III-1-2 Material for accessing competencies of experienced workers

III-1-2-a Testing the KKHS synthesis for Knowledge, Know-How and Skills

N=50 subjects working at Chinon NPP were contacted. They all had different professions and different positions. This ensured that each of the 50 cases referred to different activities: all 50 cases could be taken into account within the sample without causing any redundancy bias. They were chosen at random among the 300 professions and the 1200 employees at the NPP. For example, professions and activities were surface cleaning technician for the activity "emptying all the trashcans of the offices of the building", safety expert for the activity "daily unit safety check-up", operating reactor pilot for the activity "control room safety check-up".

The average age was 37.8 years (SD=9.3), average experience was 6.4 years (SD=6.7), with a 72% male population (a high proportion due to the preponderance of physically demanding and operational jobs at the plant as well as the small number of tertiary jobs at the NPP usually occupied by women. Plant history also plays a role in the preponderance of men working at the plant).

The profession sample grouped 40% management positions and 20% tertiary professions. At the NPP, the overall proportions are slightly different: about 25% of staff have managerial positions and about 20% are tertiary. The difference in the number of management positions could be reduced by increasing the number of subjects (but it might have created a bias by integrating similar professions within the sample) or decreased the number of participants which was not desired. The aim was to test the model; thus the need was not to obtain a representative sample of the NPP population but to undertake a test with a wide range of professions.

The results obtained were a shortened formulation of the subjects' answers, the expression of which was validated by the subjects during the interviews. The results were taken down by the PhD researcher during the interviews and then put into an EXCEL tab for statistical analysis.

For ethical reasons, the detailed results could not be included in the present dissertation in its final version: some professions being unique, the person having participated in the survey would have been easily recognized. The related appendix 6 was only accessible to the PhD Supervisor and the members of the examination board.

III-1-2-b Testing Le Boterf's model for competencies in action

The pretest of Le Boterf's model was carried out with the same sample (N=50) as above and in the same conditions.

The test of Le Boterf's model for describing professions was undertaken with 3 different professionals selected as described in section III-1-1-b. The selected professions were:

- Safety expert engineer (SE) for the "daily safety assessment" activity:
  This activity consists in a daily assessment of the level of nuclear safety on each unit of the plant. For this aim, the safety expert checks different parameters at random among a set of specific safety features in the control room and looks at the state of chosen pieces of equipment in the field and compares the results with the prescribed requirements. If any differences are observed, the SE must report it back to the Operations team and to the management, make sure that everything is done so as to return to the expected state according to the rules and ask for a safety event to be declared should it be necessary.
- Operating field worker for the activity: "locate a piece of equipment in the field".
  The activity is fairly routine and consists in locating a piece of equipment which needs working on (taking into account that the site covers several tens of thousands of square meters). To be efficient (reducing the time necessary for the intervention), the field worker usually knows the whereabouts of the equipment or at least in which part of the unit it might be found so in order to locate it rapidly.
- Operating reactor pilot for the activity: "block watch-around in the control room".
  This common activity to any pilots is designated in French "le tour de bloc" which may be translated as "block watch-around" or "block look-around. This consists in watching and checking operating parameters in the control room (see Fauquet-Alekhine & Daviet, 2015).

The material obtained was a shortened formulation of the subjects' answers, the expression of which was validated by the subjects during the interviews. This material was written by the PhD researcher during the interviews and then analysed in the light of the model.

III-1-2-c The experimental test segment

The protocol elaborated from Le Boterf's model combined with SEBE was tested on work activities linked with the sponsor's interests (essentially led by a need to improve safety objectified by safety indicators) and the needs of the present research (analyzing activities to access competencies in action).

The experimental test segment was first carried out on simulators in order to avoid safety events (see the footnote in section I-2). Testing was undertaken with increasing levels of difficulty: the first activities selected were technically simple, individual, short (about 10 min) after which came longer and more complex collaborative activities (lasting several tens of minutes). Due to planning concerns regarding simulation facilities and the availability of the professionals participating (both trainees and trainers working in shift teams) the first activities were maintenance (people not working in shift teams are usually more easily available than those working in shift teams): analysing maintenance activities allowed us to begin tests while planning the simulated operating activities at the same time.

For individual maintenance activities (TEST-IND-ROB-C1 & C2), the scenario was simple: perform a task, alone on the simulator, with no factor of disturbance. This was quite similar to real operating situations as workers often perform tasks in these conditions. For individual operations activities (TEST-IND-OP-C0 & AGT-C0), the scenarios were more sophisticated as the context of real operating situations usually implies interaction with other workers.
Concerning the collaborative aspect (TEST-COLL-OP-AGT-01), the scenario had to involve a pilot and a field worker performing collaborative activities: a principal activity “REA configuration” lasting about sixty minutes and a nested activity “local checking of another part of the circuit” associated with the assumption of a leak on the REA circuit (REA leak) lasting about five minutes. The choice of nesting collaborative activities was made because a sixty minute activity may be disturbed by at least one request from the control room (a short collaborative activity). Situations were experienced on piloting and field simulators which were coupled for the scenario. Main and nested activities were integrated in the scenario so that they could be experienced by trainees as part of an ordinary operating day on the reactor unit. The overall goal of the Operations team was to couple the turbine of the simulated unit with the fictitious national electric network. The scenario had been carefully elaborated with the help of trainers at Chinon nuclear power plant, based on external observations of work activities on other nuclear power plants, on trainer’s operational feedback, on the past experience of the trainer as a pilot and on the analysis feedback of operations work activities by the PhD researcher. “Carefully” means that several discussions were held between the trainer and the PhD researcher, then tests and adjustments aimed at ensuring that the scenario would actually include collaborative activities with the highest degree of quality made possible by the use a HF full scale simulator for the operative dimension. The scenario was designed for a 3-hour run on the simulator with a 6 member team (two pilots, two managers, a field worker and a nuclear safety expert). Description of all the activities is given in the appendix 5.

The resulting material took the form of subfilms and 3rd-person videos for each subject when recording their activity and audio files of the replay interviews. In general, replay interviews were held about one week after performing the activity and the restitution-validation phase about a week after that. Regarding the cases comparing the SEBE/SPEAC protocol with self-confrontation, each interview held was a week apart. The questions asked during the replay interviews were those developed and presented in section IV-1-1-b and appendix 26 helping the analyst to conduct a semi-structured interview. The development of these questions is discussed in section IV-1-2-a.

All these first case simulator tests contributed towards testing:

- The capacity to produce data through “Implementation, Capture and Conclusion” (ICC criteria).
- The possibility to provide a risk assessment protocol applicable to SEBE methods in high risk industries.

Some of these first case simulator tests (identified in Table 8) that contributed towards testing:

- The comparison with other methods involving an assessment of Relevancy, Completeness and Efficiency (RCE criteria): for this test phase, due to the difficulty in planning experimental SimS (the simulators are used for training and scheduling is very tight) and obtaining participants (trainees as well as trainers whose availability are not often concordant and duly difficult to line up with the availability of the simulators), only one experimental case was planned for each comparison.
- The capacity of the PhD researcher to conduct a replay interview as required by the RQ2-protocol involving qualified experts: qualified experts being from the LSE (UK) and the field experiments being in France, in addition experts not being easily available, this only concerned two experimental cases. The qualified experts were Professor Lahlou and Dr. Le Bellu (presented above).
- The capacity to analyse collaborative activities: only the collaborative activities contributed towards testing the collaborative dimension of activities.

Regarding SimS (N=6), activities, workers and analysts, methods compared and specific tests are described in Table 8.

To summarize, the experimental test segment addressed the following:

- $N_{act/exp}$ =5 different activity cases for testing the developed protocol based on Le Boterf' model in experimental test segment,
- $N_{situ/exp}$ =6 different situation cases for testing the developed protocol in experimental test segment.

Table 7 provides an overview of the experimental test segment work.

Table 7: Experimental test segment.

Situation type for experimental cases	**Methods used for efficiency comparison (RCE)**	**ICC criteria assessment**	**Development of SEBE Risk assessment**	**PhD researcher's capacity assessment**
SimS	Self-confrontation SAT SAT+description	All cases	All cases	Two cases

ICC: Implementation, Capture and Conclusion
RCE: Relevancy, Completeness and Efficiency

Table 8: Characteristics of activities in SimS to compare the developed protocol based on Le Boterf's model with other methods during the experimental test segment.

Reference	Activity (type)	Worker(s)	Analyst(s)	Comparison of methods	RCE criteria	Interview management	Collaborative dimension
TEST-IND-ROB-C1  **Figure 16: Valve.**	Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer (maintenance, individual)	Valve technician: • Gender: male • Age: 51-60 yo. • Experience: 30 y.	PhD researcher VS Trainer • Gender: male — male • Age: 40-50 yo. — 40-50 yo. • Experience: 5 y. — 2.5 y.	developed protocol VS self-confrontation	Assessed		
TEST-IND-ROB-C2  **Figure 17: Valve actuator.**	Setting cams of a valve actuator (maintenance, individual)	Idem above	Idem above but order reversed	Idem above but order reversed	Assessed	Assessed (Prof. Lahlou)	
TEST-IND-OP-C0  **Figure 18: Control room**	Block watch-around in control room (operating, individual)	Pilot: • Gender: male • Age: 21-30 yo. • Experience: 5 years	PhD researcher • Gender: male • Age: 40-50 yo. • Experience: 5 years.	developed protocol vs SAT	Assessed		
TEST-IND-AGT-C0  **Figure 19: Simulated field**	Isolating steam generator #1 due to high level of radioactivity inside (operating, individual)	Field worker: • Gender: male • Age: 21-30 yo. • Experience: 4.5 years	Idem above	developed protocol vs SAT	Assessed		
TEST-COLL-OP-AGT 01 See Figure 18Figure 19	Main activity: REA configuration Nested activity: Local checking of another part of the circuit associated to REA leak (operating, collaborative)	Pilot: • Gender: male • Age: 41-50 yo. • Experience: 13 years Field worker: • Gender: male • Age: 21-30 yo. • Experience: 3 years	Idem above	developed protocol vs SAT	Assessed	Assessed (Dr. Le Bellu)	Analysed
TEST-COLL-OP-AGT 02	Idem above	Idem above	Idem above	Idem above	Assessed		Analysed

In all cases of the experimental test segment in Table 8, the protocol that had been developed was applied by the PhD researcher. For the two first cases (TEST-IND-ROB-C1 and TEST-IND-ROB-C2), the compared method (self-confrontation) was used by a trainer skilled in self-confrontation due to his experience in simulation training debriefing as a pilot trainer (see characteristics in Table 9). For all the other cases, resulting conclusions of the SAT method were obtained after its iterative application at national level.

Table 9: Characteristics of analysts undertaking self-confrontation analysis in individual SimS

Features	**PhD researcher**	**Trainer**
Current job	Researcher	Trainer
Duration of current job (y)	5	2.5
Previous job	Researcher	Reactor pilot
Duration of previous job (y)	23	13
Academic level	Level A + 8	Level A + 2
Gender / Age range (y)	Male / 41-50	Male / 41-50

In terms of length, the material obtained was:

- subfilms each subject lasting from 10 to about 180 min in video AVI format recording the activities,
- third-person videos lasting from 10 to about 180 min in video MTS format recording the activities,
- a few third-person videos when recording some replay interviews in MTS format to get pictures for illustrating,
- audio files of individual and collective replay interviews in WMA format for post-analysis.

Overall this represented about 500 minutes of sub films, 500 minutes of 3rd-person video and about 600 minutes of interviews.

III-1-2-d The applicative test segment

When the SEBE risk assessment protocol was validated, the applicative test segment was begun: the protocol was applied in ROS for comparison with the SAT method.

Regarding ROS (N=23), activities and those carrying them out are described in Table 10. These ROS constituted the “reference situation” as in the sense of Samurçay & Rogalski (1998) (Figure 13) for future application in simulation training.

All but two of the activities in ROS were of three types: hydraulic configurations, electric configurations and periodical tests. All these activities were collaborative. All were performed by a pilot and a field worker from Operations teams except in two cases: periodical test EP-RGL4 and Application of Reliability Practices (activity type: transverse practice); these are described after the Operations team activities in the following.

The Operations team activities (reference ROS-COLL-OP-AGT 0i Ji in Table 10)
Pilots and field workers are part of an operations shift team in charge of two nuclear units (Figure 20), i.e. in charge of the operation of two reactors and related facilities. Each team is managed by an operating chief manager supported by a deputy manager and a safety operating manager (organization as of 01 Jan. 2016).

[redacted]

2 containment structures for reactors and related facilities

2 machine rooms

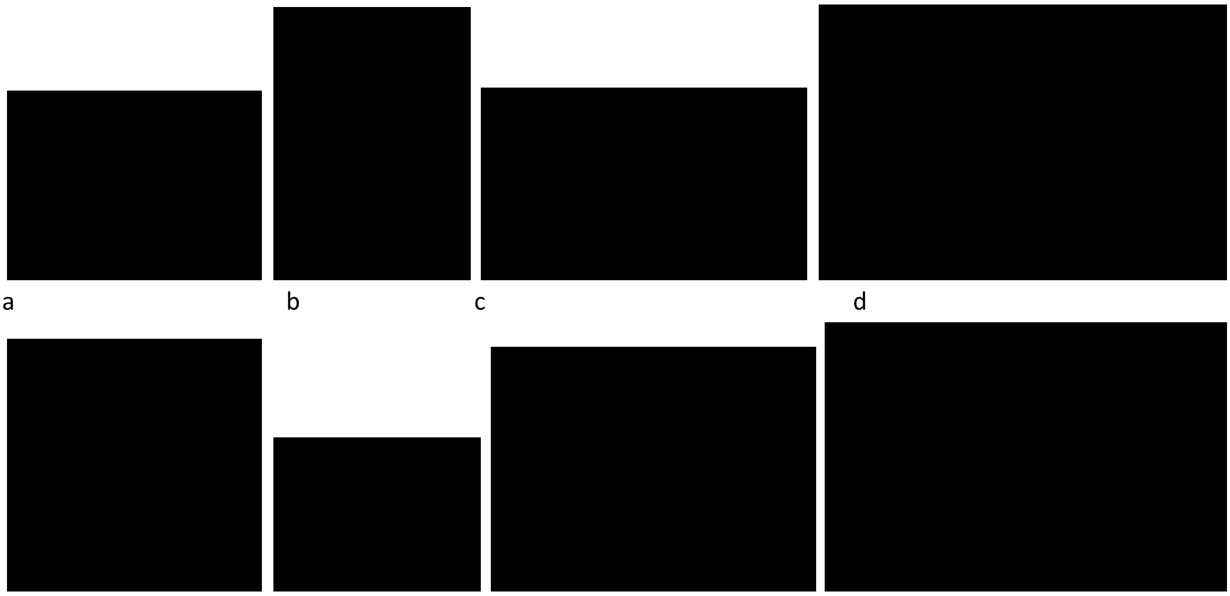
2 cooling facilities

Figure 20: Nuclear Power units at Chinon plant.
Source : Communication Dept. NPP Chinon (37CHI-DPN\Multimedias.003\Com.002\Photos\PHOTOTHEQUE\C\Chinon_B)

[redacted]

Figure 21: Nuclear Power Plant unit - principle of operation
Source : http://science.howstuffworks.com/inside-nuclear-power-plant-pictures.htm

Figure 22: Nuclear Power Plant unit - isometric schema. The control room (red rectangle) is the environment of the pilot who may (rarely) perform check-ups in the control-command area or electric facilities area. The field worker works in the rest of the plant.



a b c d

e f g h

Figure 23: Set of photographs illustrating the work environment of the pilot and of the field worker. Photos are aligned with the associated part of the isometric schema above.

Pics a / e: controlled zone facilities.

Pics b / f: containment structure, accessible only during outage.

Pics c: control room. / d: electric facilities area.

Pics d / h: machine room.

Figure 22 and Figure 23 respectively give isometric location of the workers' field of activities on the unit and insights of their occupational environments.

Figure 24: Map of the control room. Parts in red are the control panels. In blue is the desk for two pilots with computers and phones (green spots). White parts are furniture (including armchairs).

The operating tasks are carried out by pilots[10], 4 to 6 people on the two units (a minimum of 2 pilots are assigned to each control room to pilot the reactor); the pilot's workplace is the reactor control room. The rest of the team is made up of field workers who are technicians handling equipment. Their tasks concern the whole of the installation; field workers look after circuit configurations in the field (adjusting the hydraulic or electric circuits), taking measurements from physical parameters from nearby sensors, detection of anomalies and consequent diagnostics and possible participation in repairs.
The working environments of pilots and field workers are quite different. Pilots work in the control room while field workers travel all over the industrial facilities of the unit.

Figure 20 shows two of the four operating units at Chinon NPP. Each unit is made up of a reactor inside a containment structure, a machine room, and cooling facilities. The principle (Figure 21) is to maintain the fission of atoms to obtain heat which is used to transform water into steam under high pressure so as to turn the turbine. The turbine is coupled to an alternator which produces electricity. The operations teams are the heart of the NPP personnel and are in charge of maintaining and operating production capacity.

Figure 24 illustrates the space taken up by the control room of a PWR 900 MWe unit (Pressurized Water Reactor delivering 900MWe as at Chinon NPP). The pilot works in an area of 13x6m2 mostly located between the control panels (red parts on Figure 24) in the centre of which is the desk for two pilots with computers and phones. The work area of the field worker is several thousands of square meters (located in all premises illustrated in Figure 22).

In almost all cases circuit configurations or periodical tests involve one worker in the control room (the pilot most of the time) and one worker in the field (the field worker). For example, the pilot is in

[10] The control-command of a nuclear reactor is in charge of several pilots within a shift team (it cannot be done by only one person). Three of them are allowed to be in contact with the control panels: two operators and one pilot-operator (or unit-pilot) supervising the former, one manager and one deputy manager (another deputy manager is in charge of security and safety). The managers give advice but do not enter in contact with the control panels. In case of an accident situation, a safety expert is called upon to carry out checks and give advice but is also not allowed to touch the control panels: the safety expert. **For reasons of simplification, "pilot"is used to designate operators and pilot-operators**. The others are designated using their job title (Fauquet-Alekhine & Pehuet, 2016: 63).

command of a lot of equipment in the control room, but there are many other devices in the field that need visual control or direct manipulations such as valves, ventilators, electric racks. Therefore, when a procedure requires hydraulic circuit configuration involving pieces of equipment not linked with the control room, the pilot asks a field worker to take charge of the part of the work related to the field.

Periodical test RGL4 (reference ROS-COLL-OP-TT 01 in Table 10)
During the PhD, the work progress reports were regularly given to the Director of Operations at Chinon NPP. When presented with the method and results obtained in SimS, he was really enthusiastic regarding the possibilities and perspectives offered by the method. Firstly, this led him to reinforce organizational means for application in Operations teams (ROS described above and application in RQ3) and secondly to request application in the Testing teams in charge of some sensitive activities related to the control of neutronic power. He asked a special analysis of the activity “EP-RGL4”; this activity consists in measuring neutronic power parameters of the reactor in order to set up the control system[11]. His request was motivated by safety issues associated with certain phases of the activity that training and mentoring in their current form could not improve. He was also motivated by the forthcoming writing of educational specifications regarding the activity by the Training Centre at Chinon power plant in collaboration with the national operating department in the aim of launching new training simulation for EP-RGL4. From the researchers’ standpoint, the assumption was that he might be afraid of being given a simulation training session that would not be as well adapted to workers’ needs as those potentially provided by the method developed in the present study. From our point of view, it was a great opportunity to compare what the method would provide, on one hand in real time, and on the other, with the Training Center and the SAT and description-based method.

The EP-RGL04 activity involves Test technicians working together as well as several sequences during which they work with reactor pilots in the control room. Figure 25 a & b provide illustrations of different work sequences.

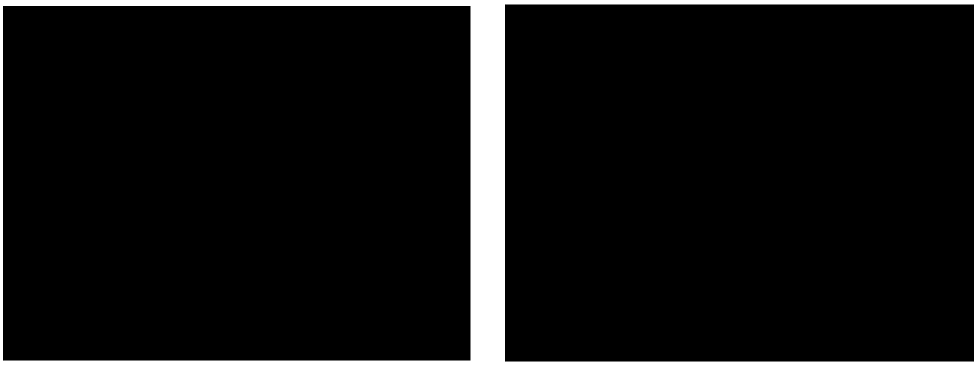
a  b

Figure 25 a & b: Test technicians involved in the EP-RGL04 activity a) together on the DMA rack (see footnote) and b)during a co-working sequence with pilots in the control room.

The main difficulty forecasted concerned the schedule: the activity was highly dependent on the maintenance program and technical repairs, whether planned or fortuitous; the analysis based on the developed protocol applied in ROS might thus be delayed several times.

Application of Reliability Practices (reference SimS-IND-Ref RP 01 in Table 10)
Reliability practices (or Human Performance tools (HP tools) in Anglo-Saxon countries) are considered as transverse professional practices[12]. They were part of a Human Performance Program launched by the production division of EDF SA throughout the French nuclear fleet in 2006. The aim was to reinforce safety and production through new areas for improvement. A part of the program was based

[11] The set up helps pilots to adjust neutronic power according to the power needs of the turbine through the DMA, device to manoeuver fuel control rod assemblies of the core; it allows the effective servo-control of the reactor.

[12] Reliability Practices might also be referred to as Non-Technical Skills (NOTECHS) as they are related to situation awareness. The NOTECHS framework consists of four main categories: Co-operation, Leadership and Managerial Skills, Situation Awareness, Decision Making (see for example Flin et al., 2003; McCulloch et al., 2009; Labrucherie, 2016).

on benchmarking abroad in different high risk industries which enhanced the benefits of HP tools. Among them, six practices were selected to be applied in French NPPs during activities. To date, they are mandatory for all the operating personal during work activities; their wide scale use explains why they are described as “transverse”: they may involve any operating profession or activity.

Although reliability practices were not applied optimally in the first five years safety indicators showed significant improvement once the project was put in place. In 2014, safety results had been stagnant for several years in this domain contrary to what was estimated possible by the head management. New solutions were sought aiming to help workers apply reliability practices in a more efficient manner. Knowing what was being developed in the framework of the PhD, the management of the Operations department asked for a new training session to be designed, the starting point being the analysis of reliability practices in action based on the developed protocol. The six practices may be described as follows (Fauquet-Alekhine, 2012d; Fauquet-Alekhine & Boucherand, 2016a):

- Pre-job Briefing: takes place after the preparation of activity, a specific phase of mental preparation and coordination for the people taking part in the intervention.
- The "Take a Minute": takes place on the workplace and just before it starts, it asks workers for analytical look at the work environment.
- Self-check: involves sequential reading of the procedure identity tag and its corresponding tag on the equipment before the implementation of an action.
- Peer-check: another person verifies the agreement between the intention announced and the draft of the forthcoming action.
- Activity Debriefing: at the end of the activity, it presents the positive and negative aspects of the activity.
- Reliable communication or 3-way communication: to ensure that information has reached the consciousness of the person doing the intervention by repeating information received and confirming it.

However, undertaking analysis of reliability practices in ROS based on the developed protocol posed huge difficulties: no personal were found to be able to apply the six reliability practices in ROS correctly and naturally. At the same time, urging a professional with skills in reliability practices to apply them as expected could lead to overloading the subject cognitively and favour the occurrence of a safety event. It was thus decided to ask a professional with skills in reliability practices to apply them in SimS. The subject was an ergonomics engineer qualified as a role-model in reliability practices and training colleagues in this field.

For all situation cases in Table 10 (N=23), the developed protocol was applied by the PhD researcher for comparison with the SAT method except for the case ROS-COLL-OP-TT 01 applying the SAT+description-based method. The resulting conclusions of the SAT method were obtained after its iterative application at the national level.

The set of situation cases sometimes permitted observation and analysis of several work activities as the field workers did not go into the field to perform one task but several. This gave a total of N=28 activity cases among which some could be gathered under one generic activity case. For example, alarm handling was observed several times and resulted in one activity case “alarm handling” although different alarms were dealt with in each situation case; similarly, hydraulic configuration was observed several times and resulted in one activity case “hydraulic configuration” although different equipment was handled in each situation case.
This resulted in $N_{act/app}$=7 different activity cases for testing the SEBE/SPEAC protocol in applicative test segment:

- Periodical test EP-RGL4 (ROS-COLL-OP-TT 01)
- Application of Reliability Practices (SimS-IND-Ref RP 01)
- Hydraulic configuration
- Electric configuration (cell lockout)

- Periodical test
- Lock out (hydraulic config.)
- Alarm treatment

Table 10: Characteristics of activities in ROS during the applicative test segment.
(NB: gender not mentioned because all subjects are male; FNR: Form Not Returned)

					Pilot or Actor		Field worker or technician	
Reference:	**Activity**	Hydraulic config.	Electric config.	Periodical test	Age (y)	Experience (y)	Age (y)	Experience (y)
ROS-COLL-OP-AGT 01 J1	Hydraulic configuration RRI/DEL (to switch lines)	X			21-30	1	21-30	5
ROS-COLL-OP-AGT 01 J2	Periodical test EP GHE 30			x	21-30	0.5	51-60	20
ROS-COLL-OP-AGT 02 J1	Hydraulic configuration ASG + Electric configuration to switch 4LLS (380V)	x	X		21-30	0.5	41-50	25
ROS-COLL-OP-AGT 02 J2	Hydraulic configuration 3SEK (in GT30)	X			31-40	0.02	21-30	4
ROS-COLL-OP-AGT 02 J3	Lock out(*) Mère SFI + Lock out(*) 6.6V + Lock out(*) Exploit SFI + alarm treatment	x	X		21-30	1	FNR	FNR
ROS-COLL-OP-AGT 03 J1	Hydraulic configuration RRI-SEC	X			31-40	2	21-30	3
ROS-COLL-OP-AGT 03 J2	Electric configuration to switch 6.6kV cells		X		31-40	2	21-30	3
ROS-COLL-OP-AGT 03 J3	Periodical test EP GHE 30	X			31-40	3	31-40	6
ROS-COLL-OP-AGT 04 J1	Lock out(*) 3SRI02RF	X			41-50	6	31-40	3
ROS-COLL-OP-AGT 04 J2	Lock out(*) 4JPT + alarm treatment	X			41-50	1	31-40	3
ROS-COLL-OP-AGT 05 J1	Alarm treatment + Hydraulic configuration for SVA conditioning	X			21-30	0.5	21-30	1
ROS-COLL-OP-AGT 05 J2	Electric configuration to switch DVI (EP DVI 20)	X			21-30	0.5	21-30	1
ROS-COLL-OP-AGT 06 J1	Hydraulic configuration RIS 128/129 VP + Electric configuration to switch RIS cells	x	X		41-50	1	21-30	3
ROS-COLL-OP-AGT 06 J2	Periodical test EP SAR 20			X	41-50	5	31-40	0.8
ROS-COLL-OP-AGT 07 J1	Periodical test EP RIS 20			X	FNR	FNR	21-30	3
ROS-COLL-OP-AGT 07 J2	Periodical test EP RIS 110			X	FNR	FNR	21-30	3
ROS-COLL-OP-AGT 07 J3	Hydraulic configuration RRI-SEC	X			31-40	1	21-30	3
ROS-COLL-OP-AGT 07 J4	Hydraulic configuration to start CEX PO (SD card damaged)	X			-	-	-	-
ROS-COLL-OP-AGT 08 J1	Hydraulic configuration GST (not completed)	X			21-30	0.5	21-30	0.5
ROS-COLL-OP-AGT 08 J2	Individual task : hydraulic configuration GSS 01 & 02 (no pilot OpJ2)	X			21-30	0.5	21-30	0.5
ROS-COLL-OP-AGT 08 J3	Hydraulic configuration to start CEX PO (framework: ASC 20)	X			31-40	8	FNR	FNR
ROS-COLL-OP-TT 01	Periodical test EP RGL4 in Test technician team			x	31-40	17	21-30	6.5
SimS-IND-Ref RP 01	Individual task : Application of Reliability Practices				31-40	2	-	-

(*)Lockout- tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that potentially dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It means that hazardous power sources must be "isolated and rendered inoperative" before any repair procedure can be started. "Lock and tag" works in conjunction with a padlock usually locking the device or the power source with the hasp, and placing it in such a position that neither hazardous power sources can be turned on nor any liquid of air gas source can be opened. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is “unlocking”.

During the applicative test segment, 3 out of the 23 situation cases were not used for SEBE/SPEAC analysis: one case because the activity turned out to be individual, one case due to a technical problem and one due to a participant-related problem. The technical problem was due to the use of a mini SD card in the camcorder inserted through a standard SD card adaptor; the electric intensity of the camcorder was probably too high which consequently damaged the cards (we do not know whether it was a problem with the camcorder or the card). The participant-related problem was due to the attitude a pilot: he made a mistake when checking the state of a pump on a control panel; this was clear during the pre-analysis when viewing his subjective video and comparing his action with what he said he intended to do just beforehand and also what he said to the field worker just after the action; during his individual replay interview the field worker confirmed this analysis on the basis of what he remembered and of the video sequence related to this exchange. Nevertheless, during the individual replay interview, the pilot explained his action as if it had been intended, not as a mistake. The interview was thus shortened as the material obtained could not be considered reliable. However, the PhD researcher did not say anything to anyone about this isolated case.

The following Table 11 provides an overview of the applicative test segment work.

Table 11: Applicative test segment.

Situation type for experimental cases	Methods used for efficiency comparison (RCE)	application of SEBE Risk assessment
ROS SimS for RP	SAT SAT+description for EP RGL	All activity cases

RCE: Relevancy, Completeness and Efficiency

The material obtained was subfilms for each subject when recording their activity and audio files when recording the replay interviews. Replay interviews generally took place from an hour to a day after the activity and the restitution-validation phase about a day later. A 3rd-person video was recorded for the periodical test EP RGL4.
The questions used during the replay interviews were those developed and presented in the appendix 26 thus helping the analyst to conduct a semi-structured interview. The development of these questions is discussed in section IV-1-2-a.

In terms of length, the material obtained was:

- subfilms for each subject lasting between approximately 60 and 180 min (except for the periodical test EP RGL4 lasting 6h) in video AVI format,
- audio files of individual and collective replay interviews of about 1h each in WMA format for post-analysis.

Overall this represented about 3300 minutes of video and 3690 minutes of interviews.

To summarize, the applicative test segment addressed:
$N_{act/app}$ =7 different activity cases for testing the developed protocol in applicative test segment,
$N_{situ/app}$ =20 different situation cases for testing the developed protocol in applicative test segment.

The collaborative dimension
For statistical representativeness, the collaborative dimension was studied among the most numerous ROS presenting similarities, i.e. those performed by the Operations professionals, the "field worker + pilot" pairing. This provided $N_{situ/app}$=21 situation cases (ROS-COLL-OP-TT 01 and SimS-IND-Ref RP 01 in Table 10 were left apart) among which 3 cases were rejected for the reasons mentioned in section III-1-2-d (individual activity instead of collaborative, damaged SD card, trust in subject) and 3 other cases were rejected because the job performance was affected by the shift schedule or a MO[13] inadequacy (2 cases that might create a bias in the data) or because the perspective taken had not been discussed in replay interviews (1 case with data missing). Finally, $N_{situ/app/coll}$=15 situation cases were analysed. Subjects' characteristics are given in Table 12.

Table 12: Subjects' characteristics for collaborative dimension analysis during the applicative test segment.

	Field workers	Pilots
Gender (% male)	100	100
Age (y)	27.6	27.6
Experience (y)	6.1	1.8
Number of subjects	15	15

III-1-2-e Technical improvement of the SEBE devices

Technical improvements were obtained by looking for new SEBE equipment respecting the following criteria as far as was possible:

- a recording system adapted to workers wearing glasses,
- small size camera so that it could be easily mounted on glasses without creating any discomfort for the user : it had to be compatible with Personal Protective Equipment,
- wide angle lens for the camera (at least 120°) in order to record both what could be in front of the subjects and see what they had in their hands,

[13] MO: Modus Operandi or procedure

- high picture definition (at least 450 lines per frame for the camera and 1280x960 pixels for the camcorder) to be able to read tags and documents in hands if possible,
- a small size camcorder to reduce participant's probability of refusal due to its weight and bulk (less than a mobile phone): field workers have to transport a lot of equipment,
- a real time view of what was filmed by the camera in order to adjust settings and to check whether what would be filmed would correspond to what was expected,
- high battery autonomy (at least 3h but this depends on the researchers' needs) in order to register several hours of activity without having to disturb subjects,
- high storage capacity for the same reason (at least 16 Go to cover 3h with the expected definition),
- standard format of data storage to transfer and read data easily with any computer,
- standard format of connection for the camcorder for the same reasons (data on SD card and/or USB connection),
- no electromagnetic disturbance due to the SEBE equipment on the industrial control-command process.

III-2 Elaborating and applying competencies in high risk industries

This was to answer:

RQ2: How are 'mobilisable competencies' elaborated through training in high risk industries?

Answering RQ2 implied applying the developed protocol on operating situations and using the subsequent results and conclusions in order to develop or adapt training sessions for workers helping them to elaborate (new) competencies and then apply them in ROS. This approach met Samurçay's recommendation (Samurçay, 2005; section II-4-2) to consider training not isolated but as a part of a professional training process. When considering Kolb's Experiential Learning Theory (Kolb, 1976; 1984; Kayes, Christopher-Kayes & Kolb, 2005), the process ends with the final objective of the concrete experience, the ROS, in which competencies are summoned. Hence answering RQ2 implied completing the entire professional training process from identifying competencies to develop until the final point, i.e. the application of these competencies in ROS. A post analysis of this professional training process should help us to understand how 'mobilisable competencies' are elaborated through training. Competencies being unobservable by nature (Leplat, 2001), we had to find associated manifestations of competencies to achieve this goal, a trivial manifestation being the job performance.

III-2-1 Method for completing a professional training process in high risk industries

The overall purpose was to identify competencies for a given activity using the developed protocol based on Le Boterf's model and to analyse how competencies would be elaborated through training and how they could be summoned and influence performance (for example: the safety, the productivity, the quality) in next operating activities.

At the same time, answering RQ2 offered the opportunity to assess the efficiency of the developed protocol and the associated professional training process at different levels. With RQ1 it was assessed at the level of the identification of input data for training programs (RCE criteria when addressing RQ1). Now it could be assessed at the level of the trainees' perception regarding their professional needs when transforming the input data into training and at the level of final performance. This was weighed up in terms of effect actually produced at the end of the training sessions (competencies in SimS) and in the work situation targeted by training (competencies in ROS). In other words, the aim was to explain how the innovative protocol could actually improve the performance of a complex socio-technical system when applied within this system. However, we kept in mind that this could be impossible due to a lack of relevant performance indicators in ROS or to the multifactorial nature of the ROS making it impossible to isolate the contribution of the method. In this case, the final level of assessment would be either trainees' perception regarding their professional needs or trainees' competencies in SimS at the end of the training session.

The strategy is summarized on Figure 26.

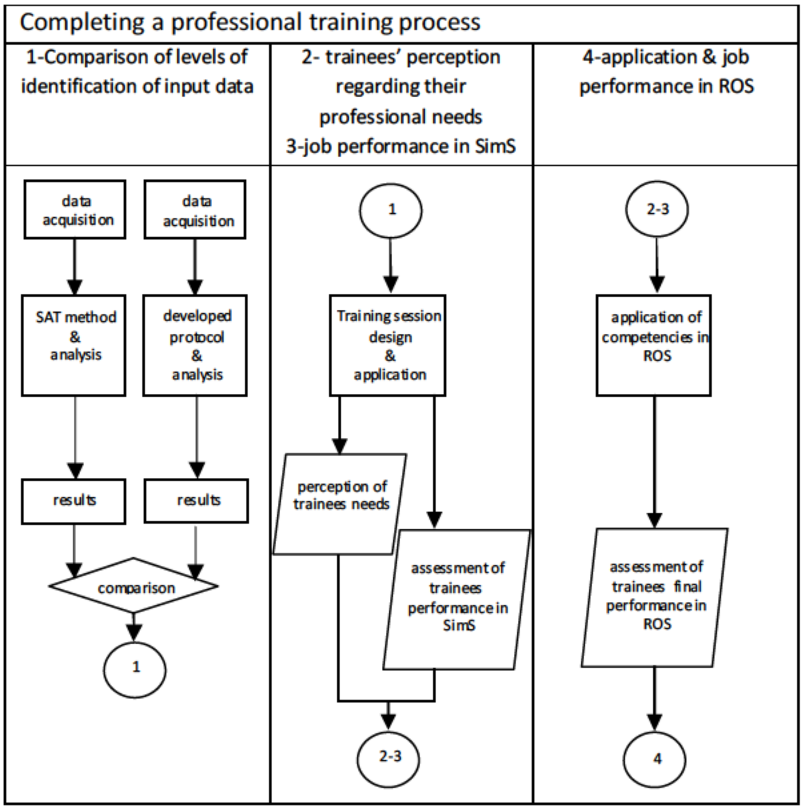


Figure 26: Strategy for completing a professional training process in high risk industries.

The aforementioned term "innovative" should be understood as "featuring new methods" (Oxford dictionary) or as the "implementation of an idea" which "leads to improving and perfecting a method" with the "sole purpose of accomplishing, at a higher standard, the objectives that were originally designed for", according to Despa (2014) quoting Despa (2013)[14]. The innovative character depicts a capacity to satisfy new needs or existing needs in a new way (Maranville, 1992). In the present case, the innovative protocol aimed at satisfying existing needs in a new way by improving and perfecting existing methods with the sole purpose of accomplishing the objectives that it had originally been designed for at a higher standard. It is important to specify and emphasize this point here because, as will be seen in the results section, this feature unexpectedly contributed towards providing keys to understanding the workings of the professionalization system.

The collected material through this progressive application (analysing ROS with the developed protocol, applying conclusions in training sessions and analysing the effects produced in the following ROS) and the analysis of the way this could work or not were expected to help us to model the professionalization cycle within the considered complex socio-technical system and thus bring elements of answer to RQ2.

As complex socio-technical systems usually suffer from administrative inertia, it was decided to undertake different cases of application in Chinon NPP and also to prospect systems other than those of Chinon NPP so that:

- the whole process could be completed for at least one of the cases in the framework of the PhD,
- the results and conclusions would not appear to be biased towards any particular model resulting from a specific context (generalization purpose).

Nevertheless, in practice, identification and selection of the field experiments were not simple:

[14] Despa (2014) distinguishes innovation from invention by referring to Fagerberg (2004): "Invention is the first occurrence of a new idea or a new concept in regards to a product or a process"; it relates to something not existing before (Oxford dictionary).

- The field experiments within the complex socio-technical system had to be identified (including identification of the possible activities), negotiated and accepted first by the management and then by those performing the activity.
- To be applied on work activities in ROS within complex socio-technical systems (usually high risk industries), the experimental plan had to be secured by integrating a protocol of risk assessment for SEBE, developed and tested in the framework of RQ1 (cf above section III-1-1-c and appendix 7).
- The operating situations identified as field experiments had to be integrated in an organizational system that would provide relevant performance indicators before applying the protocol and after applying it. It means that either a long-term performance indicator program had to be implemented already in the organization of the socio-technical system, or time and means were needed in the framework of the PhD to assess the performance in the current context, then adjust training using the developed protocol and finally assess the performance in the new context (all this within the duration of the PhD).

As mentioned above, complex socio-technical systems are characterized by inertia at different levels. The main types of inertia that could affect the study were identified at the following level:

- The acceptance of the proposal by the head management of the system:
  It could take several weeks or several months for the decision-makers to examine the proposal, take any relevant factors into consideration and grant approval or not.
- The agreement for feasibility:
  High risk industries often need to perform an in-depth analysis before implementing new devices or new methods in order to assess their positive or negative impact on the safety and the production of the units concerned.
- The effect of the innovative method on performance:
  Measuring this effect could take time. Indeed, complex socio-technical systems involve many personnel in many different work activities. To be relevant and valid, the identification of causes of increases or decreases on performance (among which possibly a lack of efficiency of the professionalization strategy for the latter) usually needs the collection and the analysis of data over a period of several months including several tens of working situations (statistical character of the analysis).

Negotiating and obtaining the field applications implied the following steps:

- Contacting the head management of the complex socio-technical systems (hereafter referred to as the partner) to briefly present the experimental need and what the benefits may be for them.
- Organizing a meeting with an ad-hoc collective selected by the head management to present in details the innovative method, the experimental need, the possible benefits for the partner and to discuss and select the possible work activities concerned (what to improve, does improvement involve simulation, how to assess past and future performance, where and when is it possible, what is the expected dynamic for improvement?). This corresponds to selecting the field experiments.
- Elaborating the experimental plan (work activity analysis, training program transformation, implementation of new training sessions, collecting data regarding past and future performance regarding the targeted work activity).
- Validating the experimental plan by the representative of the ad-hoc collective.

Applying the experimental plan and operating the field applications implied the following steps:

- Planning the training sessions, finding and summoning participants.
- Undertaking the work activity analyses by applying the developed protocol (with SEBE risk assessment before engaging ROS).

- Elaborating and validating the structure and content of the planned training sessions on the basis of results provided by the previous point with the representative of the ad-hoc collective.
- Undertaking the training sessions.
- Collecting data for performance assessment in SimS and/or in ROS, analysing and concluding.
- Sharing conclusions with participants and head management.

III-2-2 Material for completing a professional training process in high risk industries

The possible complex socio-technical systems identified were:

- Chinon NPP– EDF SA (sponsor of the present study), France, for the nuclear pressurized water reactor operation (PWR plant), professions: pilots, field workers and technicians.
- EDF Energy, UK, for the European nuclear pressurized water reactor operation (EPR plant), professions: pilots.
- University Hospital of Angers, France, for resuscitation and aesthesia, professions: physicians.
- The French Air Force for fighter jets operating, professions: fighter pilots.

The first one was chosen for obvious reasons of access. The others were chosen because we had already worked together, their professionalization strategy included training on a High Fidelity simulator, and their organization usually integrated a quality system providing different indicators of performance.

Chinon NPP– EDF SA

The activities chosen to be improved through application of the developed protocol were related to those analysed when addressing RQ1 (Table 10). They were three activities: the neutronic activity EP-RGL4, the Application of Reliability Practices and the hydraulic configuration for Operations teams.

Periodical test EP RGL 4

For EP-RGL4, the Director of Operations had asked the Training Center to implement a new training session on the simulator. After comparing the Training Center project with what the developed protocol might suggest, he asked to study possible adjustments. The reference situation was analysed in the framework of RQ1, ref ROS-COLL-OP-TT 01 in Table 10. This was initiated mid 2014; the training sessions were expected to be ready for Test technicians in 2015 and assessment of performance changes in safety and production in 2016. Associated performance results were made available by management.

Training sessions designed at the Training Center were launched in mid-2015. The first 4 sessions, summoning 14 trainees overall from the Test department, were observed by the PhD researcher who interacted neither with the trainer nor with the trainees during this observation phase. A questionnaire was filled in by the trainees after each session. It was developed on the basis of the ROS analysed in the framework of RQ1, ref ROS-COLL-OP-TT 01 in Table 10; it is called “RGL4 research questionnaire” hereinafter (see appendix 3). It included questions addressing important technical points to be worked in simulation training, chosen among those identified through the analysis of the ROS (see matrix in appendix 23) but their number was limited so that to favour the quality of the trainees’ answer. It also included questions about pedagogical aspects motivated by the fact that the training specifications accepted by the Training Center would lead to summon too many participants for a one-day session. Among the participants, $N_{SimS/RGL4}$=12 trainees filled in the questionnaire; their characteristics are given in Table 13.

Table 13: Test technicians’ characteristics for training sessions of periodical test EP RGL 4.

	Test technicians
Gender (% male)	58
Age (y)	26.8
Experience (y)	5.5
Number of subjects	12

After these training session observations, a comparison was undertaken between what was done, what was suggested by the results of the analysis of the ROS when applying the SEBE/SPAC protocol and the data collected through the RGL 4 research questionnaire. The comparative analysis was then discussed with the trainers and then with the Test Department managers for possible adjustments of the training session.

Application of Reliability Practices

For Reliability Practices (RP), the Operations Dept. management had planned to launch a new training program the design of which was in progress and the developed protocol had to provide the input data. The reference situation was analysed in the framework of RQ1, ref SimS-IND-Ref RP 01 in Table 10. This was initiated mid 2014; the training sessions were expected to be ready for Operations teams in 2015 involving members of 14 Operations teams out of 15 and a total amount of $N_{SimS/RP}$=113 subjects (see characteristics in Table 14). A significant change of performance in safety and/or production was expected in 2016. In addition, a perception questionnaire (see appendix 8) regarding the training session was presented to the trainees at the end of every session in order to evaluate their acceptance of the training session and their point of view regarding its implementation and its diffusion in the Operations department and, beyond, within the company. Associated performance results were made available by management and by analyses undertaken by the Human Factors Consultants at the NPP.

Table 14: Subjects' characteristics for training sessions of Application of Reliability Practices.

	Field workers	Pilots	Managers	All positions
Gender (% male)	100	96	100	99
Age (y)	28.4	29.2	37.8	30.5
Experience (y)	6.0	2.9	3.2	4.7
Number of subjects	63	28	22	113

It must be noticed that, for this field application, the Training Center was not involved. Training sessions were co-designed by the vice head manager of the Operations Department, three representatives of the teams chosen for their competencies and the PhD researcher; they were performed under the supervision of the PhD researcher with the help of two RP role-model managers and a Human Factors Consultant of Chinon NPP.

Hydraulic configuration

Regarding hydraulic configuration for Operations teams, a training session already existed: the CLIG session (abbreviation of the French expression "Conduite LIGnage" meaning Operating hydraulic Configurations). The reference situation was analyzed in the framework of the RQ1 analysis, under several forms, identified in Table 10 as "Hydraulic config.". This intent of contribution beginning mid 2015, it was first expected to be able to train Operations teams in 2016. However the management of the Operations department formalized this decision mid 2016 due to strategic management decisions. This was a typical illustration of administrative inertia of complex socio-technical systems at a low level (other examples will follow with higher levels of inertia). It consequently became clear that assessing performance changes in safety and production would not be possible in the framework of the PhD: a reduced number of restructured training sessions would be possible and only the performance assessment of trainees' perception regarding their needs would be planned. On this latter point, two contradictory results for the past training sessions were available: at the Training Center, past training sessions were said to be satisfactory on the basis of synthesis forms filled in by trainees at the end of each session; from standpoint of the management of the Operations Department, the past training sessions were said to be inadequate on the basis of staff's feedback after training but no written synthetic analysis was available. The method thus consisted in the following:

- obtaining the Training Center synthesis forms filled in by trainees at the 2015 CLIG training sessions (no session in 2016) and analysing the results,
- elaborating a relevant "CLIG research questionnaire" to be filled in by the 2015-trainees and then by the SPEAC-based 2016 CLIG trainees; this questionnaire would help us i)to

understand the contradictory assessment from the Training Center and from the Operations team management regarding the 2015 sessions, ii)to obtain a comparative analysis of the trainees' perception between the 2015 CLIG sessions and the SPEAC-based 2016 CLIG sessions,

- using the results of the analysis based on the developed protocol of hydraulic configurations and those of the previous points in order to redo the training session,
- negotiating the availability of the field simulator and of trainers with the Training Center in order to implement the new 2016 CLIG training session,
- negotiating participants for the new 2016 CLIG training session with the Operations Department,
- after each session, assessing the trainees' perception.

The questionnaire associated with the Training Center synthesis forms (hereinafter called the "CLIG Training Center questionnaire") was a paper form individually filled in by trainees at the end of each training session. The questions are presented in appendix 28 §I. Regarding the 2015 CLIG training sessions, N_{TC} =83 forms were analysed. They concerned all positions in the teams, and no socio-demographic data was available since this was not included in the questionnaire. For this questionnaire, the answer could be formulated three ways: yes, no, without opinion. A score was calculated per trainee by assigning +1 for each "yes" answer, –1 for "no" and 0 otherwise then adding them up and dividing by the number of questions; the overall mean score was calculated for the whole trainee sample. The greater the number of "yes" answers (an average score tending to 1), the more the synthesis was considered positive.

Regarding the "CLIG research questionnaire", N_R =80 among the 2015-trainees were contacted through their team manager on the basis of the list of attendees provided by the Training Center. They concerned pilot and field worker positions only, and socio-demographic data was available. It was decided to focus on these two positions because the training program addressed these professions and to a lesser extent the managers. For the 2016 CLIG sessions, the CLIG research questionnaire was filed in by all trainees. The CLIG research questionnaire suggested the 5 statements assessed on a Likert scale and 6 adjectives or expressions to qualify the training session. Details are given in appendix 28 §I. Additional statements were proposed for the 2016 CLIG sessions in order to take into account the specificities of the sessions (see appendix 28 §III, statement 4b to 4e). Responses on the Likert scale have been coded from –2 (strongly disagree) to +2 (strongly agree). An average score per profession and per statement was taken into account for analysis. The expected scores per statement should be between 1 and 2 for each session assessed as being satisfactory.

Regarding participants in the restructured 2016 CLIG training sessions, 3 sessions were planned in 2016 with an average of 8 participants per session resulting in $N_{SimS/HC}$=24 participants. Unfortunately, due to operating considerations and workload, the last session was cancelled (postponed in February 2017 hence after the PhD end) and for the same reasons, one field worker and one pilot were missing at the second session, leading to $N_{SimS/HC}$=15 participants. Table 15 describes the subjects' characteristics.

Table 15: Subjects' characteristics for restructured training sessions of Operations hydraulic configuration.

	Field workers	Pilots	Managers	All positions
Gender (% male)	100	100	100	100
Age (y)	28.5	24.3	36.0	29.6
Experience (y)	2.5	0.5	1.7	1.9
Number of subjects	8	3	4	15

It must be noticed that, for this field application, the Training Center was involved. In a first stage, Training sessions were co-designed by the PhD researcher and an experienced trainer (process trainer) with a professional background as a pilot and a pedagogical training; the two field simulator trainers were planned to collaborate in a next stage as they had no pedagogical training but were responsible in managing the field simulator including equipment control and maintenance as well as logistic and safety aspect. Their contribution was thus relevant for the implementation design stage. Sessions were then performed under the co-supervision of the process trainer and the PhD researcher with the help of a trainer responsible for the field simulator (field simulator trainer) and a Human Factors Consultant of Chinon NPP.

EDF Energy, UK

EDF Energy was identified as a field experiment of interest for two reasons. Firstly they were in charge of the implementation of the new European nuclear Pressurized water Reactor (EPR) in Hinkley point (UK) and have begun training future pilots. They could thus be interested in a new method despite the new building not having yet been built. Yet, they had begun to train pilots in France, at the EDF SA Training Center of Flammanville (north France) (see Figure 27) where an EPR is under construction. EDF Energy was preferred to Flammanville because of huge delays in the French construction program: we consequently assumed that engagement to apply a new method for training could also suffer delays. Secondly, it was considered relevant to test a complex socio-technical system in a country other than France: it was assumed that the administrative inertia related to this type of organizational system would suffer less red-tape[15] on the Anglo-Saxon side. This assumption came from colleagues working in EDF SA (France) and had worked at EDF Energy (UK).

EDF Energy personnel were contacted at the end of 2015. It was first expected that Operations teams could be trained at the end of 2015 but it was clear that assessing performance changes in ROS would not be possible without an actual nuclear unit that had not yet been built. What was thus considered was to compare the piloting performance in SimS before and after applying the developed protocol.

A meeting was organized at London headquarters in February 2016 gathering seven EDF Energy professionals from all over Britain: expert trainers, a work psychologist and training managers. All participants were very enthusiastic when presented with the method. At this time, the activity needing improvement had not yet been identified but it was known that it would concern the reactor pilots' work.

[redacted]

Figure 27: European Pressurized Reactor (EPR) control room simulator at Flammanville Training Center (France).
Source: http://www.corys.com/fr/mise-jour-du-simulateur-de-flamanville

However the perspective of the forthcoming referendum regarding the Brexit[16] froze any decision making. The resulting vote did not encourage the possible partners to maintain the training project: an attempt to contact the interlocutor a few months later went without answer. This goes to show that administrative inertia of complex socio-technical systems may happen at other levels than that of hydraulic configuration for Operations teams mentioned earlier, or be influenced by external politico-economical factors.

University Hospital of Angers, France

During a meeting with the PhD researcher, the head manager of the Medical Training Center of Angers (France) was told of the possibility to apply the developed protocol at the end of 2015 and showed a frank interest. He identified very soon an activity for which the trainers had difficulties to make

[15] « red tape » refers to excessive procedures, regulations and rules making it difficult to perform tasks.
[16] Brexit designates the United Kingdom's withdrawal from the European Union.

trainees improving their professional practices: the radial puncture aiming at providing a sample of blood for arterial blood gas (ABG) test. This test measures the amounts of certain gases (e.g. CO_2, O_2) dissolved in arterial blood. The radial puncture (individual activity) consists in puncturing an artery with a needle and syringe in order to obtain a small sample of blood, the most common puncture site being the radial artery at the wrist (Figure 28).

During the university year, groups of medical students are summoned to the Training Center of Angers to be trained on HF simulators reproducing the arm-wrist-hand segment complete with blood circulation (see the real operating situation on Figure 28 b and the simulators on Figure 29). The work activity is individual as shown Figure 28 a. Although it would have been more interesting to work on a collaborative activity, we had to respect the needs of our partner. The activity also presented the advantage of being easily implemented in two sessions, each gathering 12 subjects, the first one having a "classic form" (what they were used to doing at the Medical Training Center) and the second adjusted by the developed protocol, the classic form being as follows:

- introduction regarding the pedagogical goals and the structure of the session (10 min.),
- theoretical lecture and exchanges about ABG and related punctures (30 min.),
- individual simulation training (one student per simulator, 6 in all) with the help of the trainer and two role-model students and debriefing (20 min.)
- sequence for assessment of students on simulator: students performed the task on simulator and the activity was filmed for a future assessment on video (20 min.),
- debriefing of the session (10 min.).

The whole session lasted 1h30. As there were only 6 simulators available, 6 residents could come in one session. Hence the first session was duplicated and planned in two slots of 1h30 for the "classic form" and the same was done for the second session.

Unfortunately, whatever the activity chosen as a field experiment, no assessment of performance in ROS was available and its implementation was not even conceivable. The reason for this was that students came to the Training Center from different parts of the region and the assessment would have implied an enormous amount of time spent on the road for the researcher and a medical expert to be able to perform the assessments. The assessment was thus planned in SimS, at the end of the training session.

The first training session (classic training session) was originally planned in June 2016. The second training session (training based on the developed protocol) was originally planned in September 2016.

In parallel, the developed protocol was applied to a reference situation in ROS in June 2016. Then, between the two training sessions, a one-day meeting was planned in the Training Center in order to share the conclusions of the ROS analysis and to adjust the second training session.

The expected number of participants for each session was N=12 students and the PhD researcher's presence was only scheduled during the second session. In June 2016, the first session was cancelled because of a dearth of participants: this kind of training session not being mandatory in the university curriculum, only 3 students came and the trainer decided to postpone the session. After a joint analysis of the situation (Training Center team and PhD researcher), a new organizational strategy was adopted: the head manager of the Training Center recruited two MSc medical students in the research project to co-train the students and also assigned them the task of finding participants. In the case of a dearth of participants at the date of the sessions due to people dropping out at the last minute, they had to provide additional participants to guarantee a minimum number of N=12 per session (which they did) resulting in a total number of $N_{SimS/Med}$=24 subjects. Table 16 gives characteristics of residents who attended the sessions. This difficulty made the planning slipped: the first training session was re-planned in October 2016 and the second training session in December 2016.

Table 16: Subjects' characteristics for radial puncture training sessions of residents at the medical Training Center of Angers (France). Classic session designates what was done before applying the developed protocol, and the restructured session designates what was done after.

	Classic training session	Restructured training session	All
Gender (% male)	25	25	25
Age (y)	22.5	21.0	21.75
Experience (y)	4th year	4th year	4th year
Number of subjects	12	12	24

Immediately after each session, trainees were asked to fill in a form made up of a socio-demographic section, a motivation assessment section and a stress section (see appendix 9 & appendix 10). Motivation assessment was decided because the PhD researcher was afraid that the poor attendance of the first session was due to a lack of motivation. Stress assessment was decided because the PhD researcher was already involved in another research program addressing stress in simulation training at the Medical Training Center (Fauquet-Alekhine et al., 2015a, b, 2016d). It was thus an opportunity to obtain new data. To measure a possible bias due to this aspect, motivation was thus assessed. The motivation assessment was made up of three scales of the Motivated Strategies for Learning Questionnaire (MSLQ) of Pintrich et al. (1991): the Extrinsic Goal Orientation scale (4 items to evaluate the degree to which participants perceived themselves to be participating in a task for reasons such as grades, rewards, performance, evaluation by others, and competition), Task Value scale (6 items referring to the participants' evaluation of the how interesting, how important, and how useful the talk was), the Self-Efficacy for Learning and Performance scale (8 items assessing expectancy for success (performance expectations thus referring to task performance) and self-efficacy as a self-appraisal of one's ability to master a task). These scales were chosen among the six motivation scales because of their relevance regarding the experiments; the remaining scales dealing with long term academic courses (student's general goals or orientation to the course as a whole; contingency of academic outcomes on one's own effort) or anxiety were not selected. Two recent in-depth analyses showed the reliability of the MSLQ (Kivinen, 2003; Taylor, 2012) and it was successfully applied on another research theme (Fauquet-Alekhine, 2015b). Psychological stress was self-assessed by means of the Appraisal of Life Event Scale (ALES) just after the training session (see appendix 10 and Fergusson et al., 1999). The questionnaire consisted of 16 adjectives helping the subjects to rate the immediate experienced situation on a Likert scale according to two aspects: stress due to excitement and stress due to constrains. For each subject, a total score was calculated by summing the circled answers and a mean score was calculated per samples for comparison.

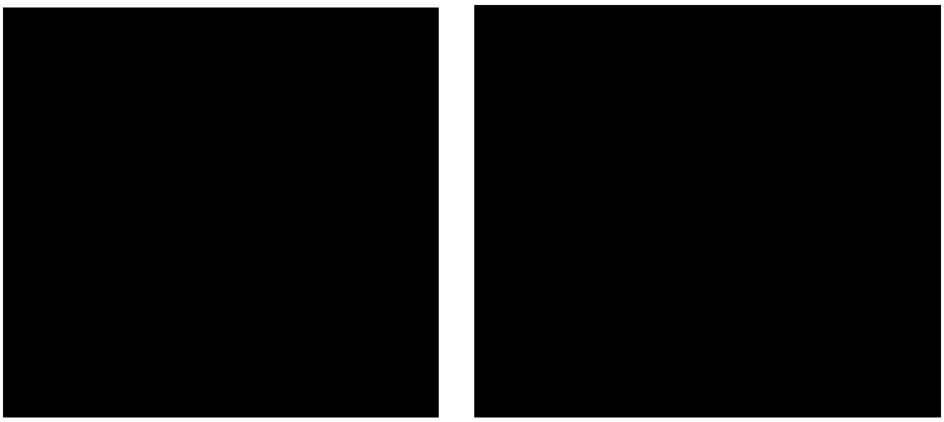
a  b

Figure 28 a & b: Radial puncture for arterial blood gas (ABG) test a)in context, b)on the wrist.
Source for 19b: http //www.decas.univ-nantes.fr/certif2009/gesttechetu2009/Site/Gaz_du_sang.html

The assessment of the resulting competencies of residents at the end of each session was carried out on the basis of third-person video recordings of their activity and using a check-list (in appendix 11: third and final version - 28 items) objectifying required items. The items were weighted by coefficients (from 1 to 3) according to their importance for the activity. The comparison of each session performance based on the overall students' score was adopted as an assessment of the efficiency of the developed protocol.

Job performance assessment was performed by a physician-trainer of the Medical Training Center and the PhD researcher.

Figure 29: Professor Granry (left), Head manager of the Medical Training Center in Angers (France), presenting the High Fidelity radial puncture simulator to the researcher (right).

French Air Force

A French fighter pilot and also training instructor on full scale simulators was contacted at the end of 2015 to be presented with the developed protocol. Several needs for training improvement were identified among which the phases of taking off or landing for novice pilots. The fighter pilot, who was very interested in this innovative method, suggested contacting the Chief of Air Force Staff ("*Etat Major de l'Armée de l'Air*") in Paris to obtain the agreement for field experiments. A letter was sent in November 2015 by the PhD researcher. A Brigadier General showed great interest when answering in February 2016 and suggested contacting the Colonel in charge of the Air Force research center in Salon-de-Provence (south France). Due to mutual planning constrains, the first exchange for introducing the project with the Colonel was in April 2016 by phone where he showed interest too. A meeting was decided with the ad-hoc members of the research center in Salon-de-Provence in June 2016 followed by a phone exchange in July.

For the Air Force, this was the opportunity to test and perhaps integrate a new method to improve fighter pilot training. For the present research, beyond the possible experiment in an additional complex socio-technical system, the advantage was to test the method with different SEBE equipment: an eye-tracking system instead of a subjective camera. The use of eye-tracking was mandatory because of the narrowness of the jet cockpit and the profusion of indicators and commands on the instrument board: from a first-person perspective, the relevant indicator of the subject's activity was not head movements but those of the eyes.

Following the meeting of June 2016, the Air Force researcher in charge of the project was excited by this method. The identified activity was confirmed: phases of taking off or landing for novice pilots on French Air Force Tucano planes (Figure 30). This presented the advantage of taking place at the army flying school located on the same site. However, she worried about the necessity of embarking additional equipment (the SEBE equipment) worn by the pilots: the fact is that any additional load or equipment had to be examined and validated by a special Air Force bureau.

a [redacted] b

Figure 30 a & b: French Air Force Tucano plane a) landing, b) flying in formation.
Source: http://www.escadrilles.org/reportages/apres-le-tucano/

End of August 2016, our worries were confirmed: the special Air Force bureau needed 15 months before giving the final evaluation regarding the use of eye-tracking in the jet with no certitude of a positive answer. Another consideration had to be taken into account: the workload of the research was planned and booked over the next two years; negotiation to reschedule it with her management appeared rather difficult. The project fell through. This was an illustration of administrative inertia of complex socio-technical systems at a greater degree than for the two previous cases.

To summarize, the field experiments remaining for RQ2 were:

- Chinon NPP– EDF SA
  Professions / Activity: pilots, field workers /measuring neutronic parameters through EP-RGL4
  Characteristics: collaborative activity
- Chinon NPP– EDF SA
  Professions / Activity: Operations team / Application of Reliability Practices
  Characteristics: individual or collaborative activity
- Chinon NPP– EDF SA
  Professions / Activity: pilots, technicians/ hydraulic configuration
  Characteristics: collaborative activity
- University Hospital of Angers, France, for resuscitation and aesthesia
  Professions / Activity: physicians / radial puncture
  Characteristics: individual activity

III-3 Ethics

Informed consents were obtained from subjects after informing them about the general purpose of the study and before going onto the field experiment (SimS or ROS) when applying SEBE methods or any recording devices (audio or video). A sample of informed consent is given in appendix 2.
This study received ethical approval of the Ethics Committee of the Dept. of Social Psychology (LSE, London, UK) and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Chapter IV - Results & Discussions

This chapter has two main sections. In each section, results are immediately followed by discussion.

Section IV-1 “Competencies of experienced workers” addresses (RQ1) “How are competencies of experienced workers mobilized and how to access them?” It presents the validation of the synthetic and consensual model for knowledge, know-how and skills under the general concept of competencies that was suggested from the literature review (the KKHS synthesis).

Then the assessment of Le Boterf’s model for competencies in action with regards to present research needs leads to the elaboration of an extended version referred to as the Square of PErcieved ACtion model (SPEAC model). This model is used to structure the protocol to access competencies in action. It is successfully tested in simulated situations during the experimental test segment and successfully applied in real operating situations during the applicative test segment. It shows that the SPEAC-based protocol is efficient at providing input data describing competencies for training programs for individual and collective activities. It also helps to characterize collaborative performance through Gillespie’s Intersubjectivity Theory by suggesting the concept of intersubjective structure of (non)collaboration. In addition, an in-depth analysis of introspection in interviews is undertaken for the first time in digital ethnographic literature.

Section IV-2 “Elaborating and applying competencies in high risk industries” addresses (RQ2) “How are ‘mobilizable competencies’ elaborated through training in high risk industries?” Input data obtained through the SPEAC-based protocol (RQ1) is used to design or adapt and apply training programs for four field experiments in two different complex sociotechnical systems (NPP and University Hospital).

It illustrates the multifactorial aspect of a successful training program: when the SPEAC-based results are combined with adapted pedagogical methods, the overall performance of the training programs may reach a high level. This is assessed through a 6-level Kirkpatrick’s extended model developed for the purpose.

It also permits the development of an excursive experiential learning cycle model combining two existing models; the resulting model answers RQ2.

In addition, tackling resistance to change during one of the field experiments, it seizes the opportunity to apply Bauer’s Theory of Resistance to Innovation and to show how the theory developed at a macroscale can be applied at a microscale.

Based on these field experiments and those which fell through, it suggests a systemic analysis of occupational training in high risk industries that may lead to further research applying Lahlou’s Installation Theory (evoked in the concluding chapter).

In the following, “MO” designates the Modus Operandi used by subjects during their work activity.

In the following, all transcribed dialogues are drawn according to the widely used orthography developed by Gail Jefferson as suggested by Hindmarsh & Heath (2000) for similar research on video analysis; further details are available in Atkinson and Heritage (1984).

The identity of the speaker is indicated in the margin, sometimes alongside a line number.

The following example shows line 1 of a transcript, in which the patient P is the speaker and the description of symbols is given after (adapted from excerpt of Heath et al., 2007).

1 P: I did <u>not</u> occasionally go to him:: (.) for: (0.2)

(0.2)	A pause timed in tenths of a second.
(.)	A pause which is noticeable but too short to measure.
him::	Elongated utterances – the longer the elongation, the more colons are added to the utterance or section of the utterance.
<u>not</u>	Louder stretches of talk are underlined.
=	No discernible interval between adjacent utterances.
(is)	Words or utterances that are difficult to hear.
.	A stopping halt in tone, not necessarily the end of a sentence.
?	Rising inflection, not necessarily a question.

Here is another example to illustrate how to draw the overlapping in the dialogue.
Maria: Its very [very tight
Jane: [yeah
Overlapping utterances are marked by parallel square brackets.

We here used additional symbols:

[…]	Speech not transcribed.
[laughs=02.4]	Laughs for 02 seconds and 4 tens of second.
[cough=02.4]	Cough for 02 seconds and 4 tens of second.
(t=12:00)	Dating of the utterance or of the beginning of the excerpt in the recording, here at time t equals to 12 min. and 00 second after the beginning of recording.
(t=1h12:00)	The same, here at time t equals to 1 hour, 12 minutes and 00 second after the beginning of recording.

Examples of application may also be consulted in Hindmarsh & Heath (2000) and Hindmarsh, Heath & Frazer (2006).

IV-1 Competencies and experienced workers

IV-1-1 Results regarding elaboration and application of the SEBE protocol

IV-1-1-a Testing the KKHS synthesis for Knowledge, Know-How and Skills

The KKHS synthesis could be described with the following intrinsic properties first formulated as hypotheses to be validated:

H1 The more the subject perceives himself competent/skilled, the more probable the answer to Q1 focuses on know-how rather than knowledge.
H2 Knowledge is perceived as the basis of competencies.
H3 Competencies improvement is related to both the number of exposures to the activity and the frequency of exposures.

Knowledge and know-how were understood here according to the synthesis given in the literature review, end of section II-1-1, as part of an overall concept of "competencies" designating knowledge, know-how and skills where knowledge is a prerequisite to know-how and skills.

To assess the validity of these properties (H1 to H3), the KKHS synthesis was confronted to the perception of N=50 workers. The mean score for S1 ("In your opinion, you are skilled in this activity?") was 1.34 on a Likert scale coded from –2 to +2, showing that subjects agreed or strongly agreed with the fact that they felt competent/skilful to perform the activity they chose to describe. All individual scores were 1 or 2 except for three of them who scored 0 (neither agree nor disagree):

- Two of these scores referred to a situation for which managers are not trained, for which knowing how to manage the situation comes from individual experience (no mentoring), and for which there is no clear assessment of success in terms of results; e.g. "dealing with an interpersonal conflict in the team" may be perceived as a success if the conflict is solved however the situation has been managed.
- One of these scores referred to a subject periodically confronted to situations exposing the subject to others whilst handing in the results of his/her work.

However, these subjects were not rejected from the sample as we were addressing the existence of knowledge and know-how, not the fact that subjects might or might not be formally trained within the professionalization strategy of the company.

Regarding Q1 ("In your opinion, what is firstly required in terms of competencies for a novice who will perform this activity?"), 64% answered details referring to knowledge, 34% to know-how and for these, the description they gave showed that this know-how was underpinned by knowledge. This allowed us to validate H2 (Knowledge is perceived as the basis of competencies). Considering subjects referring first to knowledge on one hand and first to know-how on the other when answering Q1, we tried to identify features characterizing these two groups.

Nothing could be found from average values:

- The average age for each group was resp. 37.9 and 37.8 not significantly differing according to t-test ($t(df=47)=0.12$; $p>.9$).
- The average experience for each group was resp. 6.6 and 6.3 not significantly differing according to t-test ($t(df=47)=0.39$; $p>.7$).
- The average score regarding competencies perception for each group was resp. 1.4 and 1.3 not significantly differing according to t-test ($t(df=47)=0.50$; $p>.6$).

However, when considering modal distributions, conclusions were quite different.

- The modal distribution regarding age for each group significantly differed according to χ^2-test ($\chi^2(1,fd=4)=15.03$; $p<.0001$): know-how were answered preferentially by older workers.
- The modal distribution regarding experience for each group significantly differed according to χ^2-test ($\chi^2(1,fd=3)=8.55$; $p<.04$): know-how were answered preferentially by experienced workers.

These results allowed us to add to our assumptions the following finding: the more workers are experienced (often related to older age) the more they think competencies first in terms of know-how (KH) while the less experienced they are (often related younger) the more they think competencies first in terms of knowledge (K).

Regarding Q2 ("In your opinion, when performing this activity, do repetition or frequency most improve your skills?"), 84% answered that both repetitions of exposure to the situation and frequency made them improving their activity, 12% answered only repetition, 0% chose only frequency. This allowed us to validate H3 (Competencies improvement is related to ***both*** the number of exposure to the activity and the frequency of exposure). The group of 12% answering only repetition was characterized by a low experience (4.1y compared to 6.4y for the whole sample) and a management position (66% of managers).

The overall results allowed us to validate the KKHS synthesis.

IV-1-1-b Testing the operational validity Le Boterf's model for competencies in action

Le Boterf's model was pre-tested so as to describe competencies in action. This was done with the sample of subjects as they were interviewed when testing the KKHS synthesis. Among all N=50 subjects, all of them gave spontaneously details fitting each of the three poles of Le Boterf's model. In addition, even though a full description of the activity was not expected, all participants gave several details not described by these three poles. These additional details were sorted into nine categories as shown on Figure 31.

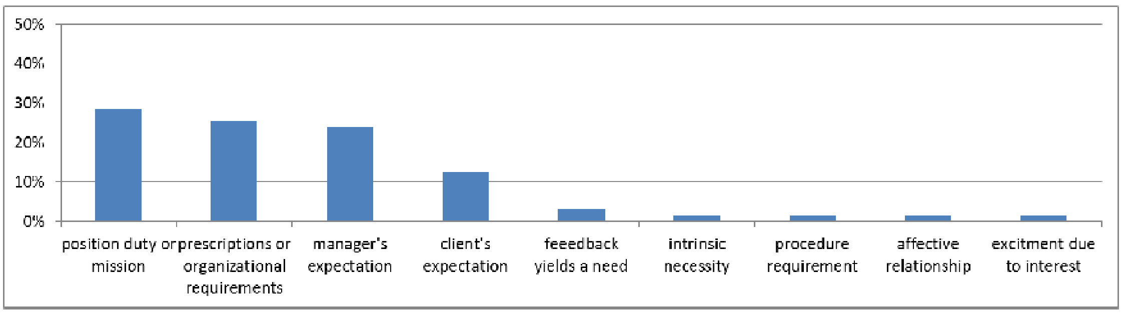


Figure 31: Percentage per categories of details not described by Le Boterf's model three poles regarding N=50 subjects describing one of their activities for which they perceive themselves competent or skilful.

The most interesting property of the categorization resulting from this pre-test was that, whatever the category, it was related to the fact that subjects *had to do it*, or, in terms of Activity Theory, to the motive(s) of their action. Furthermore, only two categories where associated with internal motives with a very low score (right hand side of Figure 31): "affective relationship" and "excitement due to interest". All other categories referred to an external obligation: expectations or prescriptions of someone else (manager, client, regulator through organization, documents, rules and laws). This exhibits that a motive was necessary to mobilize competencies in action: mobilization of competencies in action need to be trigged and the trigger relates to motives. When considering the categories of motives obtained, we may even find that motives precede willingness.

This finding thus helped us to determine that a pole was missing in Le Boterf's model to describe competencies in action. Referring to the motive(s) of the subject's action meant that a fourth pole was expected in terms of **Having to act**. Hence the triangle of competencies changed into the square action of the subject, even more precisely the square of perceived action (Figure 32). In the square of perceived action, *Having to act* and *Knowing to act* poles are mainly shaped by the organization, thus exhibiting an exogenous dimension: the former is driven by the order (client, manager) and by the definition of the task; *Wanting to act* pole is mainly endogenous, decided by the subject, subjective; *Being able to act* is both endogenous and exogenous because related to the subject's capacities (subjective dimension) and to the means allocated to the activity (organizational dimension). Here *Being able to act* must be thought devoid of the notion of "being able to act because we know" as *Knowing to act* addresses this point. It is important to note that the gerundive form refers to a dynamic process, whereas organization, procedures, rules are static.

[redacted]

Figure 32: The Square of PErceived ACtion model (SPEAC model).

One could say that adding just one pole to Le Boterf's triangle of competencies makes it rather few to change it in a model for perceived action. Yet, one must consider that adding one pole doubles the interpolar relationships: there are three within a triangle and six within a square: the side relationships and the diagonal relationships.

Considering the literature review regarding models of competencies and action, we made the hypothesis that the Square of PErceived ACtion model (SPEAC model) was the most suitable for describing competencies in action within a work activity. A reasoned application of the SPEAC model to activities may help us to analyse this hypothesis.
When a subject performs an activity, it is done by the means of actions, each having a goal. While the activity is led by a motive, action is directed by or towards a goal; it is goal oriented. For example, "hunger" is a motive (*Having to act*) that gives rise to the activity of feeding, and this activity may be composed of a set of actions. Different sets of actions can also be associated with the same activity. Feeding oneself by having a dinner at home does not involve the same actions that feeding by going to the fast-food restaurant. For this reason, a particular activity may be associated with different sets of goals, those guiding actions. One of the goals associated with having dinner at home may be to walk to the dining room; one of the goals of eat at fast-food may be to go out in the street to reach the fast food. Each of these goals is different from the other, and related to different actions. So far, the motive remains the same in both cases: "hunger". The action itself is broken down into operations (Figure 6): the "going to the fast food" action may presume to open the door of the apartment by moving the handle and pulling the door and then to close it, step down the stairs, pass the portal of the building, walk ten minutes on the sidewalk,...
In addition, as the action is goal-oriented, this assumes that there are one or more trajectories to achieve this goal. These trajectories correspond to the strategies deployed and therefore to what is

implemented (a set of actions) to reach this goal. These trajectories are not frozen: the subject is usually able to adjust the path often to optimize energy according to the principle of cognitive economy (Allport, 1904; Kongovi et al., 2002). For example, "walk ten minutes on the sidewalk" may become "drive two minutes by car" (*Wanting to act*) because a friend drove by and proposed to drop the subject to the fast-food. The trajectory can be timed or adjourned. For example, the subject, once out of the building, reminds the need of cigarettes: the subject crosses the street to go to the tobacconist (*Wanting to act*), makes the purchase and goes back to the previous activity. These examples show that an activity may be accomplished by various actions but also that an action may be part of various activities, and therefore triggered by different motives (*Having to act*). Applying the square of perceived action model (SPEAC model), *Having to act* is related to the motive "hunger" and to the goal "fast food at the end of the trip". For this aim (reaching the goal), the subject must know to act and must be able to act. *Knowing to act* allows the subject to determine the set of operations that must be carried out taking into account what can be done, that is taking into account *Being able to act*. As the trajectory to reach the goal is not frozen, it may change whilst performed. *Wanting to act* helps the trajectory to keep stable or change, as when the subject decides on the way to buy cigarettes or to take benefits of a friend's car. Similarly, *Being able to act* may lead the subject to adapt this trajectory: for example, meeting an obstacle on the way to the fast food such as men at work on the sidewalk, the subject will have to cross the street and use for a while another sidewalk than the one chosen at the beginning because of being the shorter way.

The SPEAC model could thus help us to explain the way trajectories to a goal may change by applying a pole-based protocol of analysis through the replay interview. To do so, we suggest to consider each pole of the SPEAC model and to integrate questions in the replay interview regarding both the positive and the negative aspect of the poles according to the new perspective of "negative goal" to be added in the Activity Theory as suggested by Lahlou (quoted by S. Le Bellu, 2011: 372). This relates to the necessity to take into account actions as well as non-action: “Non-actions are potential or possible actions not done but which might have been done, and are usually not observed” (Fauquet-Alekhine & Labrucherie, 2012: 79). Negative goals are related to the goals the subject does not want to reach; this approach is presented as new in that until then activities analyses focused only on positive goals, the goals the subject wants to reach. Hence the questions are basically as follows:

- Pole *Having to act* for the questions:
  What did you have to do? / What did not you have to do?
- Pole *Knowing to act* for the questions:
  What did you know how to do? / What did you not know how to do?
- Pole *Wanting to act* for the questions:
  What did you want to do? / What did not you want to do?
- Pole *Being able to act* for the questions:
  What were you able to do? / What were not you able to do?
  (in terms of means, not related to the knowledge).

As pointed out above, the two poles *Having to act* and *Knowing to act* are mainly defined by the organization before doing the activity: the worker knows usually what s/he has to do before performing the activity due to the prescription, the procedure related to the task, the manager's order, and s/he knows to do it because, as a professional identified to perform this task, s/he “obviously” had an occupational training for this purpose. The prescription, the manager's order, as well as the professional training are for a great part defined before performing the activity through the task definition and the worker’s official qualification.

These facts are considered independently from the actual degree of accuracy of the task definition and of the worker’s official qualification. This means that, as the present research deals with naturalistic occupational situations, these degrees of accuracy making *Knowing to act* are input data of the investigation and must be accepted as they are: the fact that a novice is judged by an experienced worker as someone not correctly prepared for the task but nevertheless said qualified by the management is an input data as well as the fact that an experienced worker may be an expert for the

same task. Regarding *Having to act*, if it changes significantly, then it refers to another activity. For example, when *Having to act* is defined by a procedure, if the procedure changes significantly, the activity changes too. Therefore, during the replay interview, it is interesting to question these two poles before watching the subjective video so that viewing the video does not influence the content of the answers: the subject is positioned as in the operating situation, void of a new exposure to the situation.
On the contrary the poles *Wanting to act* and *Being able to act* may be thought by the worker before performing the activity, but they may be continuously and significantly adjusted to the situation while performing the activity. These poles are less pre-defined by the organization than the two others. For the subjective video to remind the worker how performing the activity influenced the poles *Wanting to act* and *Being able to act*, they are questioned after the viewing in the frame of the replay interview.

A refined assessment of the SPEAC model to describe competencies in action was undertaken with subjects (N=3 among subjects contacted for RQ1).
For anonymity concerns, sociodemographic data (age, gender, experience…) are not given here.
The semi-structured interview was led by two questions:
Q1: In your opinion, what is firstly required in terms of competencies for a novice who will perform this activity?
Q3: In your opinion, what makes you put your competencies in action for this activity and makes you perform it successfully?
The participants gave details which then were categorized according to the three poles of Le Boterf's model:

- *Knowing to act*: What did the subject know how to do? / What did the subject not know how to do?
- *Wanting to act*: What did the subject want to do? / What did not the subject want to do?
- *Being able to act*: What were the subject able to do? / What were not the subject able to do?

For the three cases, all the details which did not match one of Le Boterf's poles did match the additional pole of the SPEAC model:

- *Having to act*: What had the subject to do? / What did not the subject had to do?

meaning that the SPEAC model was able to describe fully competencies successfully put in action from the subjects' standpoint (see appendix 4).

The assessment of the model relied on its capacity to take all that the subject had described into account, a suitable model being expected to be able to integrate the whole description or at least as much as possible. For the three professions, this was effectively achieved by the SPEAC model and it illustrated the model's capacity to provide information regarding subjects' motives as expected when performing replay interviews within a SEBE approach (see section II-3-2, § "Subjective replay interview").

The comparative analysis between the SPEAC model and other models presented in the literature review was rather fast. The weaknesses of these models regarding the purpose of the present study (describing competencies in action) were confirmed:

- the model of Davidson (1980) and the derived model of Searle (2001) do not consider competencies related to action, and its main weakness was its incapacity to take the means into account (all that the pole *Being able to act* describes),
- Gollwitzer's four "action phases" model (Gollwitzer, 1990; Heckhausen, 1991; Faude-Koivisto et al., 2009) proposing the predecisional phase, the preactional phase, the actional phase, and the postactional phase do not make link with competencies; it mainly dealt with goal intention and implementation intention, i.e. focuses on the poles *Having to act* and *Wanting to act* and the associated relationship at the expense of knowledge and means,
- The situated action models (Suchman, 1987; Suchman and Trigg, 1991, 1993; Fornel & Quéré, 1999) present action as responses to the environment and the related goals as retrofitting

constructions of the subject compared to the activity carried out; in this context, the subject does not develop the goals of the action, a modelisation that may work at the expense of what the pole *Having to act* represents,

- the TOTE (Test – Operate – Test – Exit) model suggested by Milleret al.(1960) considers the action is thus restricted to a limitative cognitive process which does not relate to competencies and remains far from the notion of activity; in particular it cannot integrate most of the content of *Having to act* and *Being able to act*,
- the model of planned action (Fishbein & Ajzen, 1975; Ajzen, 1985) presents the same drawbacks as the TOTE model,
- the Dreyfus's skills model (Dreyfus & Dreyfus, 1980) does not propose any explicit link to action; this model appears as another way to depict elaboration of competencies (like the KKHS model developed for RQ1 in the present study); motives and means are hardly taken into account,
- the revised Bloom's taxonomy (Bloom et al., 1956; Krathwohl, 2002) is an approach devoted to a mental activity and remains far from the notion of activity, thus not adapted here,
- the motor skills model of Argyle & Kendon (1967) presents a major weakness relying on a lack of descriptive relationships between competencies and action incorporated into the words "translation" and "feedback", making the means rather not clearly integrated in the model; in addition, motives and willingness are considered as a unique entity of input data of the model which reduce the possibilities to analyse their interactions.

The SPEAC model was therefore selected for further development as a basis to elaborate the expected protocol through replay interview of subjective videos.

IV-1-1-c Adapting Le Bellu's SEBE method – Testing

Based on the SPEAC model, the structure of the replay interview was therefore designed as follow:

- Before watching the subjective video, the two poles *Having to act* and *Knowing to act* are questioned.
- A subjective replay interview is performed watching the subjective video. This includes macro-introspection but direct introspection is not possible due to absence of simultaneous verbalization (or concurrent verbal report). Indirect introspection remains a possible technique but not enough developed in replay interviews according to the literature; it is thus chosen to analyse its potential contribution in post-analysis (see the discussion sections).
- After watching the subjective video, the two poles *Wanting to act* and *Being able to act* are questioned.

As pointed out above, the two poles *Having to act* and *Knowing to act* are mainly defined by the organization before doing the activity: the worker is usually aware of what s/he has to do before performing the activity due to the prescription, the procedure related to the task, the manager's order, and s/he knows to do it because, as a professional identified to perform this task, s/he "obviously" had an occupational training for this purpose. The prescription, the manager's order, as well as the professional training are for a great part defined before performing the activity through the task definition and the worker's official qualification. Therefore, during the interview, it is interesting to question these two poles before watching the subjective video so that viewing the video does not influence the content of the answers: the subject is positioned as in the operating situation, void of a new exposure to the situation. On the contrary, the poles *Wanting to act* and *Being able to act* may be thought by the worker before performing the activity, but they may be continuously and significantly adjusted to the situation while performing the activity. These poles are less pre-defined by the organization than the two others. For the subjective video to remind the worker how performing the activity influenced the poles *Wanting to act* and *Being able to act*, they are questioned after the viewing in the frame of the interview.

The structure of the SEBE/SPEAC-based replay interview offers subsequently an interesting possibility: on one hand by analysing the difference between answers to questions from one another, and on the other hand by analysing the difference between answers to questions and the resulting content of the replay interview, the analyst could identify tacit knowledge and differentiate it from explicit knowledge. Illustrating this possibility by referring to the previous example, when a subject describes the action "going to the fast food" through *Knowing to act*, s/he will likely not mention the fact that s/he crosses the street. But viewing the details of the subjective video of the action and making comments, s/he will perhaps say "I cross the street watching left and right" if the scene takes place in New York City. Crossing the street watching left and right refers to competencies related to tacit knowledge. If one of the subject's friends comes for the first time to visit the subject from Paris and ask to go alone to the fast food, the subject will likely not explain how to cross the street.

The present work aims at understanding, from field data, the nature and characterization of knowledge and know-how (both explicit and implicit) underlying the execution of a given professional activity for formalization and transmission. The final aim is to identify the necessary knowledge and know-how for this given professional activity in order to consider them as input data of the related professional training program. This requires a description and comprehension of gestures as for Le Bellu and also a description of the activity in naturalistic working conditions.

The similarities between the research cases of the two studies lie in the study of the nature and characterization of the transmission and the formalization of knowledge and know-how concerning workers in an industrial context, study aiming at improving the professionalization of such category of workers.

The differences lie mainly in the studied object (professional gesture during the realization phase vs complete activity including preparation), in the number of subjects (individual activity vs collaborative activity) and in the working context (fully controlled vs naturalistic).

Regarding the technical purpose of the two studies, the major difference lies in the final outcomes. Le Bellu's work aimed at capturing and analysing individual professional gestures in industrial environment in order to produce a detailed multimedia pedagogical tool to train workers to the gestures. In the present study, we aimed at capturing and analysing the collaborative professional activities (not only the gestures) in naturalistic industrial environment in order to know what made the competencies of workers.

Le Bellu (Le Bellu, 2011) needed to have access to a refined description of the gestures, corresponding to the level of the operation unit referring to the Activity Theory. In this perspective, a significant preparation work was necessary before video recording the gesture including adapting the environment for better external video quality, and a simultaneous verbalization was applied whilst the subject performing the gesture. As she has shown herself, these elements have decreased the spontaneity of the realization.

In the present study, we needed to have access to a description of the gestures and of the activity, and referring to the Activity Theory, the analysis was related to the level of the action unit in context. Yet the spontaneity of the activity had to be preserved as much as possible to ensure access to tacit knowledge in situation: for Polanyi (1967), tacit knowledge is intuitive and spontaneous (Wasonga & Murphy, 2006) and at the collective level, it proceeds of the improvisation that summons the group of individuals in context (Erden, Krogh & Nonaka, 2008). We needed to adopt an approach in the frame of "naturalistic studies of work, interaction and technology", which helped analysts to take into account both tools and artifacts seriously, as well as the complex array of information they provide in action and social interaction (Heath & Hindmarsh, 2002). Therefore, the significant preparation work before video recording the activity was proscribed as well as simultaneous verbalization which slows down the activity as showed by Le Bellu. The spontaneous character of the activity was easier to obtain in the present study: the activity cases studied by Le Bellu were gestures considered by the institutions as rare (occurring few times in a professional's career) or critical (with a high potential impact on safety or productivity) while, conversely, the present study was interested in daily activities. In these conditions, the real operating situation of the chosen activity could occur several times a month at a four-unit plant as the NPP of Chinon, and workers able to perform the activity were expected numerous (from the a priori researcher's standpoint). Therefore, on the contrary of Le Bellu's choice regarding the real or re-created activity protocol, we oriented our choice to a capture in real operating situation (devoid of the multimedia pedagogical tool considerations since not concerning the present study). This implied adjustment from the practical standpoint (adjustment and improvement of the video devices) and from theoretical considerations (adjustment and improvement of the replay interview and questioning the relevance of the summoned theories, in particular the Perceived Quality Theory).

Subcam – first person perspective

As mentioned above, being innovative from the technical standpoint regarding the sub-cam was easy by improving the equipment: this was actually facilitated due to technological progress. Active Media Concept (www.amc-tec.com) offered a broad range of devices with small size, high resolution, large memory capacity, and low cost. Figure 33 a & b give an insight of the devices.

Regarding the miniature camera, the model mounted on helmet (Figure 11) was not adopted because not adapted for field workers: during their job, they move a lot, sometimes between or under ducts, bend over equipment or descend/climb caged ladders; in this context, the camera-helmet is cumbersome, can cling and unbalance, and after a while may be heavy. However, as safety glasses are mandatory in the field, a cylindrical miniaturized camera mounted on safety glasses was suitable.

The selected AMC devices were:

- a square miniaturized camera 170-5MP (12x12mm, 20mm length), 600 lines colour, 170° angle lens, which we mounted on safety glasses,
- additional lavaliere microphone although the miniaturized camera had its own integrated microphone (this precaution was to ensure a good audio quality,
- micro audio digital recorder DVR-500-HD2 providing HD video recording up to 1280 x 960 pixels at 25 frames per second, integrated touch 3" colour display, three timestamp recording modes (motion detection, continuous, programmed), remote control wired and infrared, SDHC memory expandable up to 32 GB, USB connection.

These specifications were a minimum to obtain a satisfactory definition of the videos and a satisfactory view of what subjects did, including viewing the document they read.

The safety glasses used by workers in the fields had to meet safety standards so that they could be protected against mechanical choc or liquid or particle projection (including chemical products).

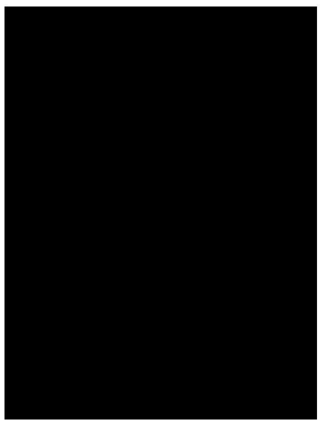
a  b 

Figure 33: Example of subjective camera device a) from left to right, mini camera on glasses, lavaliere microphone, mini-camcorder, belt holster for camcorder b) equipping a subject.

Such subjective video device was used by pilot in control room and workers in the field for first-person perspective video recordings.

When this SEBE equipment was used, subjects often asked questions regarding this equipment performance and, in some cases, told us about their own equipment for subjective video like GoPro camera or Google glasses. The subsequent question was often why we did not use this kind of material (about 100 euros) while it was less expensive than the equipment selected (about 700 euros) presented on Figure 33 and more compact. Regarding GoPro, the problem was mainly the bulk: the camera could be worn in the field (as explained for the equipment presented Figure 11). Regarding Google glasses (as well as any similar equipment) with all the hardware integrated in the frame of the glasses including the camera in the middle of the front structure, the design implied to use exclusively these glasses. In case of subjects wearing vision glasses or in case of need to wear specific glasses as Personal Protective Equipment due to risks induced by the work activity, Google glasses could not be worn and thus the experiment could not be undertaken. This remark leads to another issue: what is the best solution to mount the miniaturized camera on the glasses. We prospected to find a fast removable system adaptable to any glasses in vain. Finally, the best solution was the simpler and less expensive: the electrical adhesive tape.

Camcorder – third person perspective

The third person perspective was at first thought mandatory. It was expected to complete the first person perspective with contextual data as done by Le Bellu; the necessity of multiple videos records was already pointed out by Luff & Heath (2012).
For video recording on simulators, the devices were already in place. At the Training Center of Chinon, simulators are equipped with several articulated HD cameras and microphones which allow the observers or trainers to watch, ear and record what the trainees do and say. When trained on the piloting simulator reproducing the control room, each of the trainees wears a wireless lavaliere microphone.

For video recording during real operating situations, the case of pilots and field workers had to be considered separately.
For pilots, the use of a camcorder on tripod was envisaged. (see the following § “Bias due to 2nd or 3rd person perspective”). When using a wide-angle lens, the whole pilots’ working area illustrated on Figure 24 was covered provided that the camera was positioned at the extremity of the longer axis of the area.
For field workers moving here and there in the field, a fixed camcorder was useless. This meant that the external video recording had to follow the subject: a second person perspective was chosen.

In all these third person perspective cases, the point of view of the camera had to be carefully chosen: too close to the subjects would not give enough information because some actions or interactions would not be watched, and too far would not allow the observers to watch some of them. The adapted point of view was called “mid-shot” (Luff & Heath, 2012: 262), a medium distance that “typically captures the activities of two or three people”.

Sub-cam for a second person perspective

For workers moving here and there in the field, the observer (the researcher) had to follow the subject in the field in order to have an external point of view of the activity. A camcorder in hand could have been a solution, but this would have left only one hand free for the observer who generally takes notes.
The solution chosen was to use a sub-cam worn by the observer. Doing so, we obtained second person perspective movies of the field workers. We might think that it is directly linked with the first person perspective observer, but it is not the case as the sub-cam must not be mounted on glasses. If so, the

sub-cam would record all what is watched by the observer including the periods of taking notes which is not relevant regarding the subject' activity. For the present purpose, the subcam was planned to be mounted on the observer's shoulder and the screen of the miniaturized camcorder attached to the observer's notebook: doing so, when taking notes, the observer could check the framing of the recording. But after few tests, it showed that directing the shot of the camera by the shoulder was impossible or at least quite difficult (this implied turning the bust, sometimes bending). The final solution was a sub-cam mounted on the observer's glasses, the screen of the camcorder on the notebook and the observer had to lower his/her eyes so as to be able to take notes and film with the camera.

We noted above that for access to the understanding of the subjects' activity, it was important to have access to their thinking, which could be done only with their cooperation during exchanges with the researcher in order to analyse their activity. These exchanges (whether based on a short story, on videos, or on any other medium) were generally made through verbalization consecutive to the activity. The implementation was therefore a technique of cooperative observation (Lahlou et al., 2004) which had to be distinguished from participant observation involving the observer in the realization of the activity. In the case of cooperative observation, only subjects (the observed participants) are involved in the activity, crucial point according to Lahlou and his collaborators in terms of the subjects' motivation for carrying out the activity and the production of data. The observer therefore remains as much as possible neutral during the activity realization phase and becomes an actor of the observation in the consecutive analysis phase. The principle of participant observation is returned in cooperative observation since subjects are actively involved in the data collection and contribute to the data analysis.

Bias due to 2nd or 3rd person perspective

For the present study, although the observer (the PhD researcher) did his best not to disturb subjects in situation, being as neutral as possible, there was bias to the naturalistic character of the situations. Naturalistic observation assumes studied subjects in their state and/or natural environment, the observer avoiding the subjects notice that they are observed because this may change their behaviour. Insofar as the subjects know they are observed in the present study, as they carry an audio and video recording device and as they see in certain circumstances the observer at short distance, the observation is intrusive. However, compared to the method implemented by Le Bellu (2011) detailed in Chapter II, the degree of intrusion in the present study had to be even lower so as to preserve the highest level of spontaneity possible during the activity in situation: awareness of the situation of observation was reduced by shortening the preliminary phase limited to explaining the purpose of the observation and obtaining the informed consent of the subjects; simultaneous verbalization was not proposed and did not occur unless the subjects used it naturally. Thus, except for SimS, no situation was created for the research; it was the researcher that selected situations adapted to the study among existing training sessions or ROS proposed by the professionals for analysis. This choice was made in collaboration with the managers and the participants.

To reduce this aforementioned bias, the PhD Piloting Committee suggested leaving out the 2nd and 3rd person perspectives and only use the 1st person perspective video. Therefore 2nd and 3rd person perspectives were only used in SimS. For ROS, we only carried out observations in the control-room: as many people go in and out of the control room each hour, the observer was able to fade into the background and go unnoticed; observing in real time remained important because it helped to identify interesting sequences and hence facilitate the video pre-analysis.

Another point of importance to be adapted to the present study was the theoretical ground underpinning the protocol. Le Bellu's work aimed at capturing and analysing individual professional gestures in industrial environment in order to produce a multimedia pedagogical tool to train workers to the gestures. She needed to access a refined description of the gestures, corresponding to the level of the operation unit referring to the Activity Theory. In this perspective, the Perceived Quality Theory was well adapted to structure the simultaneous verbalization, the replay interview questioning and the analysis. It allowed the researcher to reach a deep level of description of the activity through the breaking down of operations that make up the gestures.

In the present study, we aimed at capturing and analysing collaborative professional activities (not only gestures) in industrial environment in order to know what makes the competencies of workers. We needed to access a description of the gestures and of the activity, and referring to the Activity Theory, the analysis was related to the level of the action unit in context. For this aim, it was better to base the structure of the replay interview and the analysis on a model of the action, or on a model involving competencies and action. The SPEAC model was thus perfectly suited to structure the protocol for analysis of work activities.

To summarize, the SEBE/SPEAC protocol was applied to daily occupational activities with minimum preparation of the subjects in order not to decrease the spontaneity of the realization and favor access to tacit knowledge in situations. For the same reason, no anticipated or simultaneous verbalization was required. The protocol was structured in three phases: preparation phase, capture phase, analysis phase.

Preparation phase

The preparation phase was a distant contact with the potential participants. It was structured in two steps:

- Identification of the activity occurrence and of the situation.
    - As the study deals with daily occupational activities, shift team planning and activity planning had to be analysed by the researcher in order to find opportunities of investigations matching the researcher's planning.
    - This programming had to be made several weeks in advance.
- Negotiation with the management to carry out the investigation.
    - When the activity and the participants were identified, the management was contacted for agreement.
    - When the agreement was obtained, the management displayed short information to the potential participants.

Capture phase

The capture phase was a direct contact with the participants. It was structured in five steps:

- Risk analysis researchers/managers.
- Informing participants and obtaining informed consent about the capture phase.
    - This step was brief for the following activity to be as spontaneous as possible (less than 10 min.).
    - Information includes what their contributions was for, how the researcher could disturb them during the observation, what was done with videos (analysis), how it was used (ethics).
- Installation of external and subjective video devices; framing (less than 10 min.).
- Capture (sub-cam and camcorder) of the raw activity not commented (from 15 min. to several hours).
- Storage of material and immediate short feedback; making appointments for the replay interview (less than 10 min.):
    - The main goal of the immediate short was to thank participants, remind them what their contributions was for, how it was used (ethics), what was expected from analysis.
    - The appointments were schedule within one week, and as close to the capture phase as possible.

Analysis phase

The analysis phase was structured in four steps:

- Pre-viewing of the recordings without participants and selection by the researcher of particular sequences of the video for subjects to comment them.
- Replay interview sequences with participants (about one hour per interview):
    - Informing participants and obtaining informed consent about the analysis phase.
    - Replay interview (recorded) with first actor of the situation.
    - Replay interview (recorded) with second actor of the situation.
    - Replay interview (recorded) with both actors of the situation.
    - The replay interviews has a SEBE/SPEAC-based structure adopting a sequenced questioning:
        - Before watching the subjective video, the two poles *Having to act* and *Knowing to act* are questioned.
        - A replay interview was performed watching the subjective video. The subjects were instructed to describe their activity but also to announce their goals, or intentions, objectives. These different terms were used as synonyms in order to remove any ambiguity in the term "goal". The subjects were free during the viewing to stop it when they want to facilitate the comment of a selected passage.
        - After watching the subjective video, the two poles *Wanting to act* and *Being able to act* were questioned.
    - Replay interviews were consecutive goal-oriented verbalizations which look for:
        - The subjects' feelings including the disturbance eventually induced by the protocol or the devices.
        - The subjects' goals and sub-goals before and during the activity realization.
        - The subjects' conscious mental representations of the expected results: individual and (not) shared representations.
        - The individual representation of collaborative activity.
        - How the activity is structured, at an individual level and collective level.
        - How the activity is performed at an individual level and collective level.
        - The (not) existing factors of coordination.
        - Subjects' interactions.
        - The subjects' conscious mental representations of tools.
        - Subjects' perspective-taking.

          Perspective-taking models (Krauss & Weinheimer, 1967; Krauss & Fussel, 1989; Gillespie & Richardson, 2011) allowed the understanding of the context of communication between interactants from the representation that they were organizing in alternated point of views subject/interactant. The shared understanding of the context was so built by varying the point of reference, each interactant taking place of the other. Gillespie & Richardson (2011) gave evidences of performance gain for cooperative activity when perspective-taking was applied as opposed to cases it was not.
- Post-analysis of the replay interviews by the researcher aimed at understanding:
    - The individual and collective representation of collaborative activity through the mutual goal.
    - How the content of this system is physically distributed (over artifacts related to users), socially distributed (through representations among subjects) and temporally distributed.
    - How this system is distributed over Kolb's experiential cycle
    - The individual representation of collaborative activity and the consequences for the collective subject.
    - Subjects' perspective-taking and consequences.

- The mapping out of the shared knowledge and associated communication vectors at both individual and collective levels.
- Sets of competencies required for each actor and related explicit and tacit knowledge and know-how.

  Individual and collective aspects are considered.

  For this aim, the researcher considers the content of the replay interview in three steps:

  i)Regarding each (sub)goal, the researcher tries to identify what need subjects to know how to do. In French, it is translated by the succession of two verbs, the first one is "savoir" (to know) and the second is "faire" (to do) replacing any verb of action. Obtaining answer to this question helps the researcher to identity required know-how for the activity which defines a field of competencies.

  Example: Knowing how to use a MO

  (in French: savoir utiliser un MO)

  ii)Then for each field of competencies, the researcher tries to identify what need subjects to know. In French, it is translated by the verb "savoir" (to know). The answer does not give an expression with a verb of action but "savoir" (to know) followed by a noun. Obtaining answer to this question helps the researcher to identify required knowledge for the activity related to the field of competencies.

  Example: Knowing the rules required to frame and to write a MO in order to know how to read it and understand it

  (in French: connaître les règles requises pour la mise en forme et l'écriture d'un MO pour savoir le lire et le comprendre)

  iii) The fields of competencies and associated knowledge and know-how are finally analysed according to the position within the replay interview of the elements and clues that permitted their identification. Due to the SEBE/SPEAC-based structure of the replay interview (sequenced questioning), this allows the researcher to categorize knowledge and know-how as tacit, explicit, individual or collective. In theory, this is obtained by comparing the answers provided by the subject before, during and after viewing the subjective video: for example, an element of knowledge not told whilst answering the pole *Knowing to act* but revealed later may be assumed to be tacit. However, we shall see that in practice, the method works a bit differently.

  Example: Knowing the process for updating and archiving the MO in order to guarantee the validity of the MO in hands

  (in French: connaître le processus de mise à jour et d'archivage des MO afin de garantir la validité du MO en mains)

Two types of analysis could be applied to replay interview contents. The top-down content analysis (Krippendorff, 2004) is conducted from *a priori* constructed verbal data categories, and may be assisted by specific software categorization and statistical processing. The bottom-up or inductive content analysis apply methods of systemic analysis (Nosulenko & Samoylenko, 1997) or Grounded Theory methods (Martin & Turner, 1986) to the collected data; the analyst identifies *a posteriori*, with cross-checks, the verbal categories that need to be represented (Nosulenko & Samoylenko, 2011). The material of this method gives guaranty of an exhaustive identification of competencies, know-how and knowledge from the replay interview data collection. It is a method that avoids the analyst's filter as it does not begin with hypothesis but starts from data collection: key points are marked with a series of codes extracted from the interview. Then grouped into similar concepts, the codes help to build categories constituting the basis for the creation of a "theory", working therefore as a reverse engineered hypothesis. This method was selected for the present research so as to avoid the researcher's filter influencing the analysis: this point was important because of the PhD researcher's professional background as a nuclear safety expert and Human Factors

Consultant; he thus knew a lot about work activities in a NPP and could infer comprehension of situations instead of questioning them.

- Validation (about one hour).
    - o The findings of the post-analysis were shared with the actors.
    - o It helped the researcher to validate the conclusions.
    - o It helped the actors to have a feedback about their knowledge and know-how as tacit, explicit, individual or collective and eventually to improve their meta-knowledge about the activity.

An additional step could be added in order to share the findings and conclusions with the shift team usually interested in the research and the results.

The resulting product of the SEBE/SPEAC analysis is a matrix listing per columns the fields of competencies identified (Table 17). Then for each column, knowledge and know-how are listed, first regarding the individual aspect, then regarding the collective aspect. During the post-analysis, these assumed to be tacit are highlighted in yellow. After the validation phase, the expression of the knowledge and know-how may be modified, some may be withdrawn and others added; for example, the analyst may have identified a knowledge as tacit whereas the worker identifies it as part of the fundamentals of the professions systematically taught within the initial training program for the novices; in this case the item is withdrawn. Here, it must be bear in mind that the SPEAC method application aims at identifying what makes competencies of experienced workers; we thus leave aside knowledge and know-how considered basic by the subjects.

Table 17: Insight of a typical matrix resulting from the SEBE/SPEAC analysis.

Fields of competencies	Field #1: [Knowing how to] use a MO	Field #2: ...	...
Individual Knowledge and Know-How	1-Knowing the rules required to frame and to write a MO [in order to know how] to read it and understand it 2- Knowing the process so as to update and archive a MO [in order to know how] to guarantee the validity of the MO used 3-... ...	1-... 2-... ...	...
Collective Knowledge and Know-How	1-... 2-... ...	1-... 2-... ...	...

NB: Tacit knowledge and know-how are highlighted in yellow.

The rules for writing the labels of the constituents of the matrix are as follows:

- Field of competencies
  It designates a general know-how and thus is expressed beginning with "knowing how to" followed by the infinitive of an action verb. So as to simplify the table, "knowing how to" may be omitted. This is why it is written between brackets in the model in Table 17. Therefore the expression of a field of competencies begins by the infinitive of an action verb.
- Knowledge & Know-how
  It refers to what subjects keep in memory after having had an access to some information (lessons, books, demonstration…). It is expressed by the gerundive form of the verb "to know" followed by direct object. According to the KKHS synthesis, knowledge fosters know-how. It is thus expected to be followed by the expression "in order to know how to" and the infinitive form of an action verb. However, in the aim to lighten the matrix, "in order to know how to" may be omitted. This is why it is written between brackets in the model in Table 17.

Similarly, according to the KKSH synthesis, know-how is fostered by knowledge. It is thus expected to be preceded by the expression of knowledge.

In addition, knowledge may be expressed by the verb “to know” as well as by any other synonym or expression. For example, the following may be admitted: know, be conscious of, be aware of. Other verbs may depict the acquisition of knowledge in real time: read, check, repeat.

IV-1-1-d Application of the SEBE/SPEAC protocol

The experimental test segment for individual activities (ICC criteria)

The test of the SEBE/SPEAC-based method concerned the four phases: preparation, capture, post-analysis, validation and conclusion (ICC criteria listed in appendix 1).

For individual activities, some phases needed adaptations.

The analysis of the capture phase adapted for individual activity meant that were not investigated:

- The individual representation of collaborative activity,
- How the activity is performed at a collective level,

Other collaborative-related features were also investigated despite the individual nature of the activity because some collective aspects might concern individual activities: as already mentioned by other researchers: “individual activity is just a theoretical abstraction: in social environment, any individual activity is one element of a collective activity. But, here as often, we will see that some things can be strictly theoretically false but useful in practice. And, in practice, the distinction between individual and collective activity is very useful.” (Lahlou, Nosulenko & Samoylenko, 2012: 69). This was why collective aspects were considered in the test of individual activities:

- The factors of coordination,
- Subjects’ interactions,
- Subjects’ perspective-taking.

The post-analysis phase adapted for individual activity meant that were not particularly investigated:

- The representation of collaborative activity through the mutual goal,
- The studied system distribution,
- The representation of collaborative activity and consequences,
- Subjects' perspective-taking and consequences,
- The mapping out of the shared knowledge and associated communication vectors.

The test was to assess the achievement of descriptive goals of each phase (aforementioned in the previous section) and to evaluate performance of the method in terms of Implementation, Capture and Conclusion (ICC criteria).

Assessment of the achievement of descriptive goals of each phase was undertaken for application of SEBE/SPEAC-based method to the analysis of an activity. ICC criteria sought during the test for individual (criteria in bold case only) and collective (all criteria) activities are available in appendix 24. The 46 criteria (#A01 to #C40) were built according to the expected descriptive goals of the method depicted in the previous section. According to the method using replay interview, only some sequences of the activity were submitted to replay interviews. In case of no achievement of some of the descriptive goals, an improvement was suggested.

The ICC criteria were all satisfactory for the four individual activities (Table 8: TEST-IND-ROB-C1, TEST-IND-ROB-C2, TEST-IND-OP-C0, TEST-IND-AGT-C0; detailed results in appendix 24) as well as for the collective activity (the case analysed was TEST-COLL-OP-AGT-01, see Table 8; detailed results in appendix 24). Subjects’ feelings including the disturbance due to the SEBE equipment and the research context were discussed and no special problem was noticed or reported. However, ICC criteria related to questioning the poles of the model gave nuanced results that must be mentioned here as well as other relevant particularities.

Subjects showed a spontaneous interaction with the interview material: they stopped the video player to comment a particular point of the activity beyond the sequences selected by the analyst and they showed on the screen parts of the work context to illustrate their comments.
Here is an example on Figure 34 of interaction during the replay interview of a pilot regarding the activity "block watch-around" (ref: TEST-IND-OP-01).

Figure 34: Excerpt of the SEBE/SPEAC-based replay interview showing the pilot analysing block-watch around: on the picture, the pilot rises his finger to the screen and just pressed the mouse in order to stop the replay video and make a comment.
Reference: interview replay\ OpJ 20130821\ fichier 1Go t=13:27

Replay interviews showed that questioning the poles of the SPEAC model using direct questions could disturb or confuse the subject.
Here is an example for case 01 of individual activity TEST-IND-ROB-C1:
The valve technician answering the question "What did not you know to do?" said:

Fragment 1

(Subject) S: What I don't know to do? (09.0) What I don't know to do? (02.0) I don't know (.) to (05.0)[17]

The technician opened his hands and the researcher asked:

(Researcher) R: You don't see?

S: Uh:::: (03.0) No I don't see.

Reference file: Data sub-cam et al\Rob 2013 09\IR (LSE) File 01 / 05:25

Here is an example for case 02 of individual activity TEST-IND-ROB-C2:
The valve technician had some difficulties to answer questioning *Not Having to do*.
Reference file: Data sub-cam et al\Rob 2013 12\IR (LSE) File 711_0017 (t=12:10)

Fragment 2

Researcher (R): what did not you have to do?

Subject (S): What did you not have to do? (06.5) What I did not [have to do.

[17] The translation from French to English is difficult here. The French sentence was "Qu'est-ce que je ne sais pas faire?" which my linguistics advisor and my supervisor suggested to translate using "What I don't know how to do?"; but, when adding "how" in the English translation, it may refer to "know-how" while here it must refer to "knowledge".

R: [The question is what you did not had to do and you did not do, or that you knew you did not have to do, or you did but you did not have to do, this is the question=
S: =Huhu=
R: =It may be nothing! (04.6)
S: What I (.) I don't see, no. I don't see what I did not had to do. (t=12:46)

When he was asked "What you did not know to do?" he answered after a pause of 6.5 seconds: "I don't know. I don't see what I did not know to do" and then immediately followed by a mixed: "what I did not had to do" with a silent pause of 11.4 seconds after, broken by the researcher. This answer is not satisfactory and shows that the question is blocking the subject likely by summoning directly a memory effort (Vermersch, 1994: 126). During the feedback of this interview, Professor Lahlou suggested to use indirect and multiple questions to replace each direct question.

However, in other cases, the way of questioning and explaining could produce better understanding for the subjects.
Here is an example for case 01 of collaborative activities TEST-COLL-OP-AGT-01.
Individual replay interview with the field worker: the two first poles of SPEAC model questioned seemed correctly understood by the subject and gave relevant data according to the researcher's expectation.

Subjects may answer questions not deep enough. For example, when the field worker was asked what he had not to do, he answered first on the basis of the procedure and to the pilot's requests expressed during the preparation phase in control room, then he evoked details noticed in controlled zone and was ready not to describe them. The researcher had to stop him and ask for precise description:

Fragment 6
Field Worker (FW): […] After it is things I noticed locally (.) uh:::: but however no [the:::
PhD researcher (R): [Wait, things you noticed locally (.) What for example?
Reference: simu MS(I) 2013 12\ MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-AgTR\ DSCN4411.AVI (t=02 36)

This gives an example of the necessity for the researcher to be ready at any time to lead and help the subject to a complete answer. Despite preliminary explanations given by the researchers regarding what they are seeking, subjects do not evaluate how details may be important. This may be due researchers' explanations not clear enough, or to the fact that they are not used to analysing activities to appreciate well the value of details, or to their desire to give other details at once. The trap to be avoided by the researcher is to focus on writing or written notes or on the next questions and being unable to notice this very short evocation.

Collective replay interview with both pilot and field worker for case 01 of collaborative activities TEST-COLL-OP-AGT-01 showed that the two first / last poles of SPEAC model questioned seemed correctly understood by the subjects and gave relevant data according to the researcher's expectation; replay interview caused subjects spontaneous participation and gave relevant data according to the researcher's expectation.

Direct questions were avoided: following the individual interviews, researchers found it more relevant to question SPEAC model poles through selected video sequences. The purpose was thus to identify sequences were generating conflict or accordance between poles: subject 1 wants but subject 2 cannot, subject 2 wants and subject 1 can and wants for example.
Doing so, it led to investigate perspective-taking and perception of collaborative activities in cross-replay interview (see next section investigating collaborative dimension).

Tacit knowledge may be accessed through the SEBE/SPEAC protocol.
Here is an example of access to the individual implicit knowledge "know the reading rules of a RFFL in order to interpret it" for individual activity TEST-IND-AGT-01:

Whilst questioning *Having to act* and *Knowing to act*, deviations from what must be done appeared. The subject explained having to correctly read the whole form before leaving to go in the field (file 1 Go t= 01:40 reading the line about ARI at t=02:50) and during self-confrontation (file 400 Mo t=14: 49), the subject explained having forgotten to read the first lines in red stating the ARI port. This explanation was induced by a comment from the subject himself watching the video "this I should have read it before" followed by a video break done by the researcher who incorporated the comment "you should have read it before? '' The subject explained he passed quickly to the first box of the flowchart forgetting to read the few lines in red just above: they were additional comments to describe the task done inside the boxes.

The tacit knowledge was not on the fact that he had to read but on the fact that he had to understand these additional comments apparently respecting writing standards which are not taught. The subject did not remember how he learned how to understand it.

The metaphorical language used by the subject could help to identified tacit knowledge.

Here is an example of individual activity TEST-IND-OP-C0:

The potentially tacit knowledge demonstrated by the pilot (see appendix 25, table 16 (column “understanding the control panel”) by comments “read information, sometimes fast” and “understand information, sometimes fast” was identified through descriptions of block-watch around made by the pilot emphasized by a metaphorical expression he used during the self-confrontation interview. To depict the way he was checking monitors, the pilot said “je regarde si ça tire droit” (I see whether it draws straight). When asked what he meant, the pilot explained that he did not read the values of parameters on this monitor; for some of them or certain indicators, it was easier and faster to check a signal position rather than read the value according to the scale of the monitor to compare it with the expected value (this can be done by looking at the graph showing the evolution of the indicator on the monitor; if this line is straight, this means the indicator has kept a constant value over that time period). According to him, this was done without losing any reliability on values. When he was asked whether this practice was his own, he said that most of his colleagues (even all) did so. When he was asked where he was taught this practice, he could not find any answer.

This tacit knowledge, identified through the use of a metaphorical description of the work activity, gave us an interesting topic of research to investigate: the associated assumption was that this experienced pilot (duration in the position: 5 years) developed an implicit knowledge which was shared with experienced peers but perhaps not with the novices. This point gave rise to additional experiments in order to characterize this potential typical implicit knowledge using SEBE by comparing the practices of novices and experienced workers (published in Fauquet-Alekhine & Daviet, 2015); this work is not presented here.

Subjects gave spontaneously useful feedback.

Here is an example for case 01 of individual activity TEST-IND-ROB-C1:

After the replay interview with the researcher, the valve technician insisted to give his feeling about the subjective video and accepted to be recorded. Here follows an excerpt of the transcription of this exchange: “tomorrow, it is something [the video] I want to present to my trainees. […] I think that the person, when he will have seen that and perform the act, will think about how he can do not to be in the mess […] It is good to watch the gesture.” The worker left the researcher’s office with a copy of the video and the week after, he was using it to train novices. The valve technician was also quite impressed by the knowledge “ask for help” according to the researcher’s analysis also named “know to address” according to the trainer. It was presented as a tacit knowledge and indeed, the subject seemed doubtful about it. But after one week, while met in corridors, he explained to the analysts that he had discovered through the SEBE how important this knowledge could be.

Reference file: Data sub-cam et al\Rob 2013 09\actor's feeling vs IR

To conclude about results regarding ICC criteria:

- The participants accepted the use of the sub-cam very easily and seemed to participate in the experiment and replay interview with enthusiasm.
- The researcher/analyst must emphasize the help provided by the participants to the work analysis. This helps the participants to make sense about what s/he is about to undertake with the researcher (C03).
- Tenses of verbs used are important whilst questioning the poles of the SPEAC model. The appropriate tense questioning the two first poles of the SPEAC model is the present. This helps the subject to think and answer as if he was about to perform the task, which is the sought effect. The appropriate tense for the last poles is the preterit, because it helps the subject to recall what he did, what he just viewed during the self-confrontation, which is also the sought effect (C04/C09).
- Participants had sometimes difficulties to answer direct questions of poles of the SPEAC model likely by summoning directly a memory effort (Vermersch, 1994: 126). Especially questioning *Having to act* keeps the subject close to the procedure (C04/C05). The qualified experts (Professor Lahlou and Dr. Le Bellu) suggested to use indirect or devious and multiple questions to replace each direct question (C04/C05). A series of possible questions are thus listed in appendix 26.
- Questions asked by the PhD researcher in the aim of identifying goals and sub-goals must be more numerous and more frequent (C16/C19). A series of possible questions are thus listed in appendix 26.
- Questions about the four poles of the SPEAC model in their positive and negative form gives indeed relevant information which come in addition or complete what produces the self-confrontation. It even gives access to the subject's knowledge and know-how even when they are not summoned during the studied situation.
- The questioning of each pole completes one another (C05/C09). For example, answering *Wanting to act* brought forgotten items for *Having to act*.
- Answering questions of *Not Having to act* integrates implicitly the will to ignore "absurd way to act" (C05).
- During the interview, metaphorical expression describing the work activity may help to identify key points related to competencies.
- Potential typical implicit knowledge may be characterized using SEBE.
- Subjects elaborate indirect mental representations when the targeted piece of equipment is unknown. This may rely to a combination of episodic memory and enactment to be analysed.
- The ICC criteria were overall reached with success or found solutions for improvement.
- Subjects had a positive feeling after the replay interview (C40) and said they were enthusiastic about the experiment.
- From the technical standpoint, synchronizing any camcorder or video record together (including the simulator system) is crucial for easier analysis and audio plug must be checked.

The limits identified were:

- For this test phase, only some sections of the subjective film of the activity were watched. Despite the facts that this was not disputed by the subject performing the task and that the SEBE/SPEAC-based method gave results in terms of what make the competencies of the worker, it is important to keep in mind that when applying the method, it might be worse viewing the whole activity or several long parts of it. This would lead to longer phases of reply interview and consequently of analysis.
- Using direct questions to explore the poles of the SPEAC model appeared not always efficient: we had difficulties in obtaining relevant information with such questions whilst applying the protocol in some cases. Answers to these questions must be reached through indirect questions as suggested and illustrated during the experiments by Professor Lahlou and Dr. Le Bellu (see appendix 26 for a list of indirect questions).

The experimental test segment for collaborative activities

The experiment involved subjects (a pilot and a field worker) in performing collaboratively a main activity "REA configuration" lasting about 60min. and a nested activity "local checking of another part of the circuit" associated with an assumption of a leak on the REA circuit (REA leak) lasting about 5min. Description of the activities is given below. Situations were experienced on piloting and field simulators during a scenario that summoned a piloting team (1 manager, 1 supervisor, 2 pilots), 1 safety engineer and 1 field worker.

Overall, the ICC criteria obtained with these collaborative activities confirmed findings obtained with individual activities. Detailed results are given in appendix 24.

In particular, replay interviews using indirect questions whilst questioning the SPEAC model poles allowed the subjects to answer easily and gave access to relevant information.

During the replay interview with both subjects, the two first / last poles of SPEAC model questioning seemed correctly understood by the subjects and gave relevant data according to the researcher's expectation. Replay interview caused subjects' spontaneous participation and gave relevant data according to the researcher's expectation.

> Direct questions were avoided: following the individual interviews, researchers found it more relevant to question SPEAC model poles through selected video sequences. The purpose was thus to identify sequences were generating conflict or accordance between poles: subject 1 wants but subject 2 cannot, subject 2 wants and subject 1 can and wants for example.
>
> Doing so, it led to investigate perspective-taking and perception of collaborative activities in cross-replay interview. This work is presented in a section thereafter.

Field worker's activities

Observing the field worker's activities and viewing related movies allowed us to summarize them in the following timeline in Table 18.

Table 18: Timeline of the field worker's activities

task \ time	10:45	10:52	11:00	11:07			11:15	11:22	11:30	11:37				11:46			11:51	12:00					12:07	co-workers
waiting for pre-job briefing																								f.worker alone
Pre-job briefing for turbine coupling activity																								team+safety engineer
preparing REA configuration																								f.worker and OCL, then f.worker
communication pilot/field worker					(1)						(3)		(4)			(5)								pilot+f.worker
co-preparation of REA configuration							(2)																	pilot+f.worker
moving to controlled zone, dressing; entering																								f.worker alone
REA configuration																								f.worker alone
exchange about radiologic concern																								OLC+f.worker
exchange about radiologic concern																								supervisor+f.worker
exchange about REA leak																			(6)			(7)		pilot+f.worker (then supervior)
REA leak action																								f.worker alone

Legend:

	field worker engaged in activities
(4)	field worker engaged in collaborative activities with pilot (number refers to note)
1	co-presence in control room: field worker asked for preparation
2	co-presence in control room: co-preparation
3	phone: field worker asked action on SES pump and help for radiologic concerns
4	phone: interlocutor is pilot then supervisor (radiologic concerns)
5	attemps to reach control room to specify controlled zone phone number
6	phone: local control for pressure meter
7	phone: feedback control for pressure meter then radiologic concerns with supervisor

The collaborative activity began at 11:13. During the following time, the field worker was involved in three tasks (see Figure 35):

- REA configuration involving the steps: preparation, co-preparation, moving and entering controlled zone, equipment configuration (about 87% of the time),
- Radiologic concerns for REA circuit (about 9% of the time),
- Local check of equipment for REA leak (about 4% of the time).

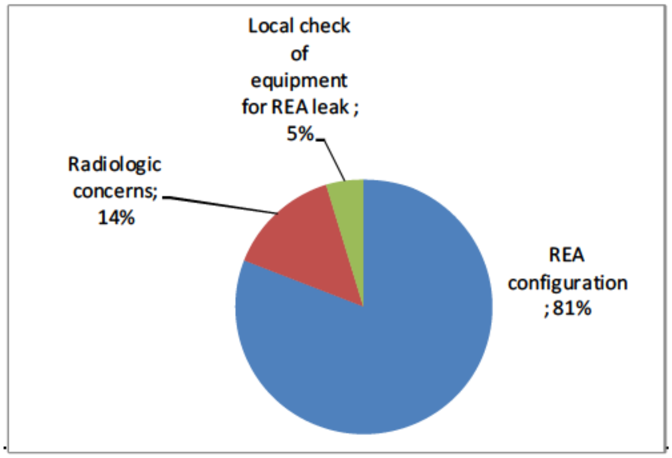


Figure 35: Distribution of the field worker's time for performed tasks.

[redacted] a

[redacted] b

[redacted] c

[redacted] d

[redacted] e

Figure 36 a to d: Field worker's activity - Excerpts from external video record (a: exchanging with the pilot; b: checking equipment and MO in controlled zone; c: exchanging with the pilot by phone) and from the field worker's subjective view whilst performing "REA configuration activity" (d: exchanging with the pilot in the control room; e: in the controlled zone, inserting a key into a lock, valve wheel and lock in left hand, key and pen in right hand).

Figure 36 a to d show pictures extracted from the third-person video and the field worker's subjective view whilst performing activity "REA configuration". The main goal of the activity is to set up pieces of equipment related to the basic system named "REA" according to the modus operandi (MO) to allow the one-way valve 5REA545VL operating after works of maintenance. For this task "REA configuration", the field worker had first to prepare his activity and discuss it with the pilot in the control room. Then he had to move to the "controlled zone" (radioactive part of installation) and had to find the pieces of equipment and apply the associated lines of the MO.

Reference: simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR SLB-Op1\DSCN4414.AVI (t=07:58)

Reference of external videos for the field worker: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 ZC

Reference of subjective videos for the field worker: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 AgT R

Pilot's activities

Observing the pilot's activities and viewing related movies allowed us to summarize them in the following timeline in Table 19.

Table 19: Timeline of the pilot's activities

task \ time	10:45	10:52	11:00	11:07			11:15	11:22	11:30	11:37			11:45					11:55										12:11	co-workers
block-watch around and current piloting action																													pilot alone
Pre-job briefing for turbine coupling activity																													team+safety engineer
turbine coupling activity (increasing nulear power)																													2 pilots+supervisor
communication pilot/field worker					(1)						(3)			(5)						(7)				(7)			(7)		pilot+field worker
co-preparation of REA configuration							(2)																						pilot+field worker
managing the instability of the reactor																													2 pilots+manager+supervisor
reducing nulear power (due to technical problem)																													2 pilots+manager+supervisor
thinks about radiologic concerns for field worker													(4)			(4)													pilot+supervisor
dealt communication for others															(6)														pilot+interlocutor+supervisor
analysis of the MO and drawings for REA config.																													pilot alone
exchange about REA leak																													pilot+OCL
analysis of the MO and drawings for REA leak																													pilot alone

Legend:

	pilot engaged in activities
(4)	pilot engaged in collaborative activities with field worker (number refers to note)
1	co-presence in control room: field worker asked for preparation
2	co-presence in control room: co-preparation
3	phone: field worker asked action on SES pump and help for radiologic concerns
4	due to immediate previous exchange between supervisor and field worker
5	phone: field worker gave information about phone numbers
6	phone: a radiologic technician for the supervisor
7	phone: local control for pressure meter

The collaborative activity began at 11:13. During the following time, the pilot was involved in seven tasks (see Figure 37):

- Block-watch around and current piloting actions (about 12% of the time),
- Turbine coupling involving the step: increasing nuclear power but not the pre-job briefing done before (about 2% of the time),
- REA configuration involving the steps: co-preparation, analysing MO and mechanical drawing (about 33% of the time),
- Managing instability of reactor (about 12% of the time),
- Reducing nuclear power (about 12% of the time),
- Radiologic concerns for REA circuit (about 16% of the time),
- REA leak involving the steps: exchange with OCL, analysis of mechanical drawing (about 14% of the time).

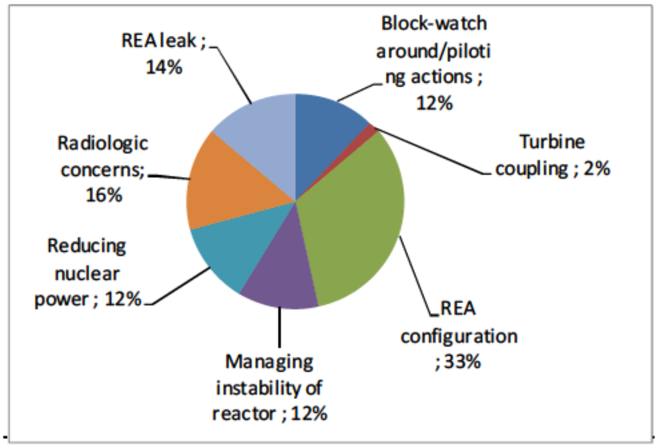


Figure 37: Distribution of the pilot's time for performed tasks.

a [redacted]

b [redacted]

c [redacted] d [redacted]

Figure 38 a to d: Pilot's activity - Excerpts from external video record (a: exchanging with other pilots in the control room; b: exchanging with the field worker in the control room) and from the pilot's subjective view whilst performing activities in the control room (c: exchanging with the field worker, d: acting on a control panel).

Figure 38 a to d show pictures extracted from external video recording and from the pilot's subjective view whilst performing activities in the control room. During the task "REA configuration", the pilot had to exchange with the field worker to prepare the task, then remain at the disposal of the field worker in case of need, and wait for the feedback of the field worker following the achievement of the task. Meanwhile, the pilot had to deal in the control room with other tasks to be performed in parallel of the task "REA configuration".

Reference of external videos for the pilot: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 SdC
Reference of subjective videos for the pilot: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 Op1

The nested activity "local checking of another part of the circuit" associated with an assumption of a leak on the REA circuit (REA leak) was initiated by detection using a flow meter indicator in the control room. The Operator in Charge of Lockout (OCL) played by one of the trainer came to meet the pilot while the main activity "REA configuration" was in progress. The OCL discussed the possible source of the leak with the pilot (Figure 39) and they concluded that the pilot should call the field worker to perform a local check of the 5REA502SP pressure meter.

[redacted]

Figure 39: Excerpt of the pilot's subjective video whilst discussing with OCL (hand on the right), analysing together the MO (left) and the mechanical drawing (right) to make assumptions about the leak source. They decide to check the pressure meter 5REA502SP.

Reference: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 Op1\FNND0873_20131205114329.AVI (t=17:49)

In the appendix 25 describing the design of the activities for the experimental test segment, we wrote that the studied tasks had been carefully designed to involve subjects in collaborative activities. It was worth to verify the collaborative character of the activities actually performed by subjects in the simulated situation: we had to verify that we obtained what we expected. For this aim, both main and nested activities were here assessed by the researchers regarding the criteria of collaborative character of an activity in tables of appendix 24.

The collaborative character of the activity was discussed in interview and analysed by the PhD researcher with the help of qualified researchers (Dr. Le Bellu), work analysts (Chinon NPP), and trainers (Training Center of Chinon); all these people are designated as "researchers" in the following.

The cross-replay interview was chosen as the relevant moment to cross-confront what the pilot and the field worker thought about the collaborative dimension of the activities. After a rough description of what the researchers meant by "collaborative activity" (working together and sharing the same goal whilst being engaged in the same activity), the subjects were asked whether they perceived themselves involved in collaborative activity or not.

Here is an excerpt of recording (fragment 9) when the researcher asked the workers their point of view regarding their perception of the main activity "REA configuration".

Fragment 9

R to both:	Hence I have a question(.) the first one is that : in your opinion(.) were you involved in a collaborative activity related to the field worker's one?
Field worker (FW):	No (5.41)
R to FW:	Why?
FW:	Well(.) he knew what I was going to do because: they [the pilots] need to know but (1.81) well that(.) that did not concern him directly I think.
R to P:	You share?
P:	Yes(.) I share yes(.) this is why::: as I told you earlier if:::: if the the result he would have said it to someone else(2.32) if he had made a report directly to the OCL saying he had unlocked it:: it did not bother me too much because I did not have an expectation regarding that.
R to P:	Ok(.) And if FW does something on his circuit which is not right(1.04) you are bothered?
P:	(2.03) well, it may generate some incidents in principle=
R to P:	=But because in the interview we had with FW just before, FW says: I must not generate water movement which could bother you(1.37) Thus uh:: there are things in the collaborative activity which are some 'expectations from the other'(.) and there are things which are some 'absolutely not expectations from the other'=
P:	=Yes(.) the risks=
R:	=Yes(.) But if I do it that way(.)I am not saying that anybody on the plant is in collaboration with you?
P:	(5.50) Well, everybody may have an impact::: [laughs=1.67] on: [laughs=3.11] yes.
FW:	(3.40) No no(.) [smiling to P] no in this case I was thinking(.) the goal:: uh the goal:: uh of(.) of the circuit configuration and of unlocking[18] uh:: well:: that will not change his:: his shift [well(.)
R:	[yes=
FW:	=on the other hand(.) being aware(.) that we are going to do that(.) and saying that perhaps if you get an alarm on this(.) it is perhaps us=
R:	=yes=
FW:	=due to that(1.08) so(.) but the activity itself(.) the fact that we unlock and configure afterwards uh::: it is not::(2.00) well that does not affect them in the right way.

This exchange must be considered in parallel of what was presented in section III-1-2-c and in appendix 25: "The scenario had been carefully elaborated with the help of trainers of the Nuclear Training Center of Chinon, based on external observations of work activities on nuclear power plant, on the operational feedback of the trainers, on the past experience of the trainer as pilot and on the analysis feedback of the operations work activities of the PhD researcher. "Carefully" means that several discussions between trainer and PhD researcher, then tests and adjustments aimed at ensuring that the scenario would actually include collaborative activities with a highest degree of quality made possible by the HF full scale simulator regarding operative dimension."

The above transcription describing the subjects' feelings about the main collaborative activity "REA configuration" lasting about 60 min. showed:

- a deviation regarding the sought goal of the experiment (designing a main activity which is collaborative),

[18] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a padlock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

- an opposite assessment compared with the researchers' standpoint.

However, their collective feelings expressed in fragment 9 were in opposition with what was said by the field worker during the individual replay interview. Before preparing his activity and then exchanging with the pilot, the field worker went to see one of the pilots with the OCL (Operator in Charge of Lockout played by one of the trainer) and told him about the forthcoming activity. During the individual replay interview, the field worker explained the importance of his activity for the pilots:
Reference: Data sub-cam et al\simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-AgTR
File audiovideo: DSCN4411.AVI (t=09:10)

Fragment 9bis

FW:	Well they <u>must be updated</u> about what we::: what we do in the <u>field</u> because it had(.) especially here it had:: a direct impact on (0.90) on <u>their</u> activities.

The nested collaborative activity (REA leak) was based on the fact that the pilot should encounter a problem of leak with REA basic system and had to call the field worker for him to check a piece of equipment. According to the simulation design, this was a collaborative activity lasting about 5 min. nested in the main collaborative activity. The transcription of the cross-replay interview giving the subjects' feeling about this nested activity follows:
Reference: Data sub-cam et al\simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-AgTR
File audiovideo: DSCN4411.AVI (t=13:15)

Fragment 10

R to both:	And so here[19] we are in a <u>collaborative activity</u>?
FW:	[here=
P:	[yes=
FW:	=yes.
P:	Yes if I detect something and I ask him to go in the place:: to <u>see</u>(.) yes

The pilot and the field worker at the same time said: "yes".

The conclusion for the main collaborative activity was that subjects did not feel they were sharing the general mutual goal related to the task and did not feel as if they were performing the same task together whereas they had felt it for the nested collaborative activity. As they shared the same perspective-taking, the intersubjective structure of non-collaboration was verified.

These results highlighted unexpected findings:

- While the subjects' perception of the collaborative dimension of the two activities was expected to be similar, it was not the case.
- While the subjects' perception of the collaborative dimension of the main activity was expected to be effective, it was not the case.
- The perception of the collaborative dimension of the two activities was different for the subjects and for the researchers.

Further analysis could help researchers to understand these differences. This could be achieved by characterizing the activities. The following is a list of what could be objectified:

- Regarding organizational interactions, an asymmetric social relationship between subjects involved in collaborative activities was observed: the pilot operated and the field worker manipulated. There was a double subordination relationship: hierarchical and operative. The hierarchical subordination stood in the administrative and organizational subordination *de facto* of the field worker to the pilot, and the operative subordination was linked with their respective position within the collaborative activity: most of the time, the pilot asked the field

[19] Here=Nested collaborative activity REA leak.

worker to do; the collaborative activity started from the control room, not from the field. However, their own degree of responsibility was equal as they were equally responsible of their own part of the collaborative activity. The relationship of the collaboration was here subordinate: the organization defined the field worker as a subordinate of the pilot. We factually observed it as the field worker was several times asking pilot's agreement to act. We thus identified subordinate (vs: peer) type collaborative activity characterized by the fact that there is a subordination (vs no subordination) between the subjects involved in the collaborative activity.

- Regarding the organizational workload, a misbalance was observed between co-workers, in terms of number of tasks undertaken by each (task-context (a)symmetry), and in terms of disturbance (disturbance (a)symmetry). It concerned the context of the task and the disturbance. The pilot was involved in performing more tasks than the field worker whilst performing the collaborative activity and seemed more disturbed during this period. This implied the field worker's comprehension regarding the not-immediate availability of the pilot in order to understand that for the pilot, any exchange with him was necessarily interactionally organized. It was the case when the field worker asked for help about radiologic concerns and could not obtain an exchange by phone at once with the pilot (see timeline at t=11:42). This also questioned the field worker's capacity for perspective-taking in order to have comprehension regarding the not-immediate availability of the pilot.
  Task-context and disturbance (a)symmetry could be quantified. The quantitative assessment of the task-context (a)symmetry implied to count the number of tasks taken in charge by each subject; here, with 3 interlaced tasks for the field worker and 7 interlaced tasks for the pilot, there was task-context asymmetry. During the collective replay interview, the PhD researcher counting with subjects the amount of tasks for each one suggested that this implied for the field worker a mono-collaborative situation (with the pilot) while the pilot was involved in a multi-collaborative situation (with the field worker, another field worker played by a trainer, the other pilot, the chief supervisor). Subjects confirmed and gave details to demonstrate that it is always so[20].
- Regarding the physical aspect of the organization, the distance between the co-workers might be of influence: did they work in the same place (co-present collaborative activity) or not (remote collaborative activity)? In the present case, most of the time, it was remote collaborative activity since the pilot stayed in control room while the field worker went onto the field simulator. This implied adapted means of communication.
- Regarding organizational chronology, in the case of the main activity, we were able to observe the synchronous nature of participants' actions: the concordance of the timelines of subjects proves it (timelines in Table 18 & Table 19). This implied a good coordination and a possible delay induced by one subject for the other from the observers' viewpoint. It was the case for example when the field worker asked for help about radiologic concerns and could not obtain an exchange by phone at once with the pilot (see timeline at t=11:42).
- Workers' interaction was characterized by the feedback of one subject's actions on his collaborator's forthcoming actions or decisions and its kinetic. In other words, the matter was to assess whether or not a part of the work to be done by one subject depended on the result of the other's work, and if yes, was this dependence immediate or delayed? Was the kinetic short, medium or long term type? This consideration was worth to be noticed because in some cases, one subject might wait for the other's action (implying attention would be mainly devoted to the collaborative activity) whereas in other cases, one subject would allow him/herself to do something else meanwhile (attention would be distributed among several activities). For the nested activity, subjects expected immediate action feedback (short kinetic) and for the main activity "REA configuration", the action feedback was deferred (medium or long kinetic) as clearly expressed by subjects during the cross-replay interview. The pilot describing his feedback expectation regarding the field work actions for the main activity "REA configuration" said:

[20] Data subcam et al\simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-Coll\711 : t=27:50 (audio)

Reference: simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-Coll\DSCN441.AVI (t=02:12)

Fragment 5

Pilot (P): If:: if the:: the result he [the field worker] said it to someone else (2.30) if(.) if he had given feedback directly to the OCL as he had locked-out uh (.) Me it (2.04) it wouldn't have disturbed me more than that because I did not have expectation regarding (0.54) regarding that.

- Workers' interview was also characterized by the property "subordinate/peer type". The field worker explained that whatever happened, if the initial demand did not come from the pilot (subordinate property, the pilot being at a higher hierarchical level than the field worker), then the pilot would not feel concerned and the activity would not evolve as collaborative. This is illustrated by the next fragment:
  Reference: Data sub-cam et al\simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-Coll
  File audiovideo: DSCN4415.AVI (t=11:30)

Fragment 12

P: [I think that=

R: [yes?

P: =I think that, yes we:: we are summoned to collaborate more than:: more than we [turns head towards FW] more than we realise.

FW: well me I see it, like where (.) when the pilot when the pilot when it is the pilot who calls(.) he is concerned. If it is not the pilot who calls(1.70) he does not need to (1.00) well it doesn't concern him. (1.24) I see it like that.

R: Ah yes!

FW: (3.39) when we go to do configuration: I don't know:: the hot water circuit uh:: well (1.09)

P: [laughs=0.82]

FW: they want to know because if he has an alarm on the hot water circuit he will know that it is us but uh:: after what we shall do on this uh:: unlike the RRA configuration where here:: it is him who gives us the activity or the direction where here there is that and that and that(.) you call me when you go(.) here(.) here yes(.) but if not::::

During the cross-replay interview, the pilot did not react on this proposal, and unfortunately the researchers forgot to react too.

This last point needs a parenthesis regarding the interview practice. Viewing the interview recording associated with fragment 12 showed that the PhD researcher, while listening, was already preparing his next question. This completes the warning written after fragment 6:

- the trap to be avoided by the researcher is to focus on writing or reading notes or on the following questions and thus missing an important element of the narrative,
- complete comprehension of a situation implies asking for the standpoint <u>and</u> counter-standpoint of each participant.

This remark illustrates the importance of the analyst not taking notes during the replay interview (thus recorded) and remaining fully concentrated on what is said.

The set of properties identified through the characterization of the activities allowed us to establish the following conclusions or to make the following assumptions in terms of factors that would make the subjects perceiving the main activity as collaborative:

- The asymmetric social relationship between subjects could not be a factor favouring the non-perception of collaboration as it was existing similarly for all activities in daily job as well as in the simulated situation (main activity and nested activity). The fact that collaboration was perceived for the nested activity showed that collaboration could be effective in the subjects' mind with this asymmetry.

- For the same reason, the remote character of the collaborative activity was not selected as a factor of influence.
- The task-context asymmetry in terms of number of tasks undertaken by each co-worker could be considered at the outset as possibly favouring the non-perception of the collaborative dimension as there was asymmetry for the main activity (collaboration not perceived) and symmetry for the nested activity (collaboration perceived). The same for the disturbance asymmetry in terms of request for activities other than the main activity and the nested activity. However, either this asymmetry had no influence on the perception of collaboration, or this asymmetry was influencing subjects differently in the main activity (the pilot was disturbed but not the field worker) and influencing subjects similarly (neither the pilot nor the field worker was disturbed) in the nested activity and yet their perception was similar in both cases. Therefore, it would be difficult to explain the influence of this factor on collaboration perception.
- The synchronous nature of participants' actions was already a factor favouring the collaborative perception.
- The kinetic feedback could favour collaborative perception but the experiment would show that only short (or immediate) kinetic feedback would permit the activity to be collaborative; this factor was not selected as relevant because we postulated that long activities could also be collaborative and perceived as such under conditions to be determined.
- The resulting assumption from fragment 12 was that the property "subordinate/peer type" seemed to influence the collaborative character of the activities.

After this analysis, only one property remained as a factor influencing the perception of collaboration: the "subordinate/peer type" property. The solution was thus to make both pilot and field worker at the origin of the demand or to put them at the same level regarding the origin of the demand. This means to break the subordinate property of the demand. This led to a new circuit followed by the demand:

OCL (Operator in Charge of Lockout) -> field worker + pilot

Hence a new experiment was undertaken on simulators two years later (TEST-COLL-OP-AGT-02) in the same conditions than the first one except a difference for the main activity "REA configuration" (difference with previous experiment underlined):

- The OCL comes to see <u>together the field worker and the pilot</u> and explained <u>them</u> the configuration to be done.
- The field worker prepares the task alone.
- The field worker goes and sees the pilot and explains to him what he plans to do in controlled zone, asks co-analysis and agreement.
- The field worker goes in controlled zone and here he called several times the pilot for help.

Two hypotheses were investigated.

The first hypothesis (H1) was that putting them together at the same level regarding the origin of the demand would change the "subordinate/peer type" property referring to the demand.

The second hypothesis (H2) was that H1 validated would make both pilot and field worker feel sharing the general mutual goal related to the main collaborative activity and make them feel performing together the same task as for the nested collaborative activity.

The results were the following:

- H1 was validated,
- H2 was rejected: subjects had the same feeling and gave the same answers.

This led to the conclusion that factors other than the "subordinate/peer type" property had to be worked in order to make subjects feel the collaborative dimension of an activity and particularly share the overall mutual goal and feel as if they were performing the same task together. This was to be investigated in the applicative test segment.

In addition, the SEBE/SPEAC method allowed us to work on perspective-taking during the cross-reply interviews by making a co-worker perceive some of the feelings of his/her colleague while watching the video recorded by the other. In the case studied, while the field worker was calling the pilot on the phone because he needed something done as well as information (see timeline at t=11:42), sometimes the pilot refused and asked him to wait or find a different solution.

Fragment 7

Pilot (P): If you want let's timed uh:: wow uh [laughs] because [laughs, short breath] here I am (.) I am a l bit in the… in the shit!

Ref: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 Op1

File: FNND0873_20131205111827.AVI (t=24:34)

When asking the field worker during the replay interview if he had any idea about what was going on in the control room, he answered he had some idea. But when viewing the subjective video of the pilot during the cross-replay interview, he said he understood better.

This kind of situation illustrates how little workers working together on a daily basis know about their colleagues' activities and suggests that knowing what the colleagues do and go through could help them act or react differently towards them.

The experimental test segment for RCE criteria

Applying the SEBE/SPEAC protocol for the $N_{act/expe}$ activities helped us to produce a matrix {fields of competencies VS knowledge & know-how} for each activity according to the model given in Table 17: each hyphen in the matrix was counted as one Knowledge & Know-How (examples are given in appendix (12 to 23) of matrixes with the count of Knowledge & Know-How in the final table of each appendix). For the other methods, data were made available by the Human resource Dept. of the NPP or by the Training Center and the same method was adopted to count Knowledge & Know-How. All this helped us to calculate the values of performance criteria (RCE criteria for the assessment of relevancy, completeness and efficiency); these are summarized in Table 20.

The first column refers to the activity which the comparison addresses, the second column refers to the method compared to the SEBE/SPEAC method, other boxes give ratios of the criteria. Regarding performance ratios, a value greater than 1 illustrates a higher performance of the SEBE/SPEAC method; when the denominator is null, the ratio is detailed. Regarding efficiency ratios, a value greater than 1 illustrates a lower performance of the SEBE/SPEAC method. In order to calculate these ratios, for the two first activities, analysts were asked to provide a table in which they listed knowledge identified as necessary and relevant to perform the task. Knowledge related to individual dimension had to be separated from knowledge related to collective dimension. In addition, knowledge regarding tacit dimension had to be identified by the analyst and discussed and validated with the participant during post-analysis. The numbers obtained were then used to calculate the ratios. For the two last activities, the analyst applying the SEBE/SPEAC method was asked to do the same. Regarding the other methods involved in the comparison, the protocol applied provided a list of knowledge related to the activity. An additional analysis was therefore undertaken to separate and count individual knowledge from collective knowledge and to specify whether some was tacit or not. The numbers obtained were then used to calculate the ratios.

Table 20. RCE criteria (Relevancy, Completeness and Efficiency) - ratios of criteria of the methods applied per activities in the experimental test segment (SimS)

Activity (reference)	Analysis method	Individual knowledge & know-how	Collective knowledge & know-how	Tacit knowledge & know-how identification	Cost (Man-Days)
Setting of a neutral point on a pneumatic actuator of valve TEST-IND-ROB-C1	Self-confrontation	1.75	3.00	29.4% / 0%	1.0
Setting of cams of a valve actuator TEST-IND-ROB-C2	Idem	1.45	3.00	34.7% / 0%	1.0
Block watch-around in control room TEST-IND-OP-C0	SAT-based method	1.44	2	46.1% / 0%	0.7
Isolating steam generator TEST-IND-AGT-C0	SAT-based method	17	10/0	59.3% / 0%	0.7
Hydraulic configuration of REA circuit Pilot Field worker TEST-COLL-OP-AGT 01	SAT-based method	10.50 9.00	15/0 13/0	66.6% / 0% 65.0% / 0%	0.7 0.7

Values were calculated as follows.

For the SPEAC method:

The SPEAC method theoretically implies 1h for each phase: capture, analysis, replay interview, post-analysis and validation. This gives 5h. This phase duration is imposed by the availability of the workers: in order not to alter their work schedule too much and for the management to accept the application of the SPEAC protocol, we agreed to limit the capture and the meeting for analysis to 1h. each. However, aware that time taken usually exceeds that planned, we considered for the calculation that each phase could last from 1 to 2h and we majored the calculation taking the higher value into account. Nevertheless, each phase did not involve all participants: half concerned analyst and worker and half concerned the analysts only leading to an average participation of 1.5 person per day. We thus considered that applying the SPEAC protocol would take 10h. At the same time, as applying the SPEAC protocol was achieved in one day work or two half-day work, we considered that the SPEAC protocol took one full day overall for an average of 1.5 people. In terms of cost expressed in man-days, 1.5 persons being involved in the analysis, this gives a maximum possible value of **1.5 man-days** for the SPEAC protocol.

For the SAT method:

The deployment of the SAT method involves an initial analysis at national level and then an involvement of teams in each NPP for adjustment at a local level. At each level (national or local), 5 to 10 professionals gathered around a table for a brainstorming session over several days spending about half an hour per activity. The NPP fleet encompasses 20 sites; so as to completely achieve the process, at least 2.2 to 4.4 man-days are necessary ((5 to 10people) x (20 sites+1national) x (½)/24h)=2.2 to 4.4). For the calculation, we took the minimum possible value of **2.2 man-days**.

This mode of calculation was also adopted for the applicative test segment.

Values show that the SEBE/SPEAC method had always a higher performance, identifying up to 9 times more knowledge than other methods and at least 1.45, distinguishing tacit and explicit knowledge in all cases whereas none of the other methods did it (see appendices 12 to 23). Values also show a higher efficiency of the SEBE/SPEAC method compared to the others with a same duration of acquisition-analysis of data but a lower cost in terms of people involved.

The applicative test segment for RCE criteria

RCE criteria were elaborated after analysing the individual replay interviews in the frame of the SPEAC protocol compared with the SAT method combined with a description-based method in one case (see Table 10). The $N_{act/app}$ different activity cases and the resulting ratios for the RCE criteria are summarized in Table 21. Knowledge & Know-How were counted as described above for the experimental test segment.

Table 21. RCE criteria (Relevancy, Completeness and Efficiency) - ratios of criteria of the methods applied per activities in the applicative test segment (ROS and SimS)

Activity (reference, if specific)	Analysis method	Individual knowledge	Collective knowledge	Tacit knowledge identification	Cost (Man-Days)
Periodical test EP-RGL4 (ROS-COLL-OP-TT 01)	SAT+description-based method	3.00	5/0	50% / 0%	0.6
Application of Reliability Practices (SimS-IND-Ref RP 01) pilot	NA	54/NA	8/NA	17.7% / NA	-
field worker	SAT-based method	18	8/0	17.7% / 0%	0.7
Hydraulic configuration pilot	SAT-based method	8.5	23/0	51.2% / 0%	0.7
field worker	SAT-based method	6.7	23/0	54.0% / 0%	0.7
Electric configuration (cell lockout) pilot	NA	12/NA	24/NA	61.1% / NA	-
field worker	SAT-based method	2.7	25/0	47.9% / 0%	0.7
Periodical test pilot	SAT-based method	1.9	25/0	52.3% / 0%	0.7
field worker	SAT-based method	9	24/0	54.0% / 0%	0.7
Lock out (hydraulic config.) pilot	SAT-based method	12/NA	24/NA	55.5% / NA	0.7
field worker	SAT-based method	2.1	24/1	52.8% / 0%	0.7
Alarm treatment pilot	NA	9/ NA	5/ NA	21.4% / NA	-

Comments: "NA" is Not Available; "5/0" means 5 items were found with SPEAC when 0 with SAT.

Values were calculated as for the experimental test segment except for the periodical test EP RGL4:

For the SPEAC method:

The maximum possible value of 1.5 man-days for the SPEAC protocol was selected when applied to one worker. When applied to a collaborative activity, 2 workers (pilot and field worker) were involved, but considering each profession separately, maximum possible value of **1.5 man-days** for the SPEAC protocol has to be selected.

However, specifically to the activity EP RGL4, the analysis was much longer than usual. The specificity of the activity implies to follow 2 people for capturing the activity during a while day. Overall, the SPEAC protocol application took 2 days instead of one. The resulting value for the SPEAC protocol cost was **4 man-days**.

For the SAT method:

The minored value of **2.2 man-days**.

For the SAT+descriptive method applied to the periodical test EP RGL4:

The descriptive method came in addition to the SAT: after the whole SAT process for which we selected the minored value of 2.2 man-days, we add the contribution of the descriptive method. It implies meetings of an average of 4 people (trainer, manager, and role-model technician) distributed over time resulting in about one day, giving thus 4 **man-days**. The final value is thus **6.2 man-days**.

These results in Table 21 (RCE criteria) confirm the results obtained in the experimental test segment undertaken in SimS (Table 20): the SEBE/SPEAC method is costless and more efficient. As for the experimental test segment, the proportion of tacit knowledge and know-how ranges from 50 to 70% except for "application of RP" ad "Alarm treatment": about 20%.

In addition, regardless the subjects' competencies associated with the technical aspect of their job (knowledge regarding the equipment and the way to act on, the industrial process), observations highlighted general professional practices that seemed to enhance workers' performance. At an individual level, a major difference determining the effectiveness of a field worker was their ability to structure activities and sequence reasoning and gestures. Some undertook overall control of the activity or of a phase of activity before moving onto another phase; this assured detection of non-compliance vis-a-vis expectations. Those who applied overall control always structured the activity. On the collective level, some of the workers coordinated their forthcoming actions by calibrating what they intended to do prior to the activity and especially through a preliminary work to share the same mental representation of the up-coming activity and the respective contributions. The time suitable for these professional practices appeared to be the pre job briefing or at least a time spent before performing the activity during which workers discussed of what they had to do. All this was related to transverse professional practices in the sense it was not devoted to hydraulic configuration or electric configuration but applicable to any task. The SPEAC analysis showed that the time suited to this precondition was the pre job briefing. This aspect of the job was analysed farther when addressing the collaborative dimension of the activities.

The subjects' perception regarding the SEBE/SPEAC method used for analysing their activity was also assessed using the questionnaire in appendix 8, questions 2 to 10 where "the studied RP" was replaced by "your activity". The Cronbach alpha was α=0.75 for the field workers and α=0.60 for the pilots showing a good consistency of the data. For the whole sample, α=0.66 also showed a good consistency of the overall data drawn on Figure 40. Some of them even spontaneously gave their feeling at the end of the replay interviews; it was not easy to record them because, most of the time, subjects waited the end of the interview to express their feeling and sometimes the recording devices were already stopped. These are a few samples:

> During the cross replay interview, a pilot said: "it is nice anyway to watch what we did. It allows us to better understand what we did… to see the situation, be confronted through the video, it is another angle."
> His co-field worker added: "alongside your study, I think that it may also be useful in helping the cohesion of the team: the fact that the field worker sees what the pilot does and that the pilot sees what the field-worker does permit to understand stereotypes and permit to enhance the collaborative work from a human standpoint."
> Both concluded that this method should be applied to all of their colleagues working in pairs in shift teams.
> [ROS COLL OP AGT 01 J1 – RIW coll J1 – audio file at t=01:23:00]
>
> During the individual replay interview, a pilot said: "It is interesting to watch ourselves working, we see things as such the fact I speak too fast or the fact that I cut off my colleague's speech, this was something interesting because finally I am not sure of the message given to him." […] "I should be very interested in knowing what you will do with all that."
> [ROS COLL OP AGT 02 J1 - OpJ1 – audio file at t=01:04:15]
>
> A pilot said: "I found the approach interesting; it permits to identify behaviours that may need corrections, as, for example, the fact that I spoke in the field worker's stead during the preparation phase of the activity. […] There are [also] things that we can do that appear to be good practices and we are not aware of them."
> [ROS COLL OP AGT 04 J2 –OpJ2 – audio file at t=00:38:00]
>
> A field worker suggested that this method should be applied to every member of shift teams: in his opinion, everyone should benefit from this method. This was said after the replay interview and not recorded.

Analysis of the answers provided on a Likert scale coded from –2 (strongly disagree) to +2 (strongly agree) showed that, from the trainees' standpoint:

- analysing the subjective film was a real added value compared to a method without subjective film (i.e. a method said "classic"): average score 1.55 with 100% ticked 1 or more,
- the method induced faster progress than with a "classical" method: average score 0.76 with more than 62% ticked 1 or more,
- the overall perception was positive (not constraining for them, innovative, worth to be applied to other work activities): average score 1.24 with more than 89% ticked 1 or more,
- the method had interest to be applied to colleagues (as illustrated in the above testimonial): average score 1.31 with more than 96% ticked 1 or more.

The average scores for each question for pilots and field workers is given on Figure 40. Calculation of χ^2 showed that the pilots and field workers' distributions were similar: $\chi^2(1,fd=8)=0.76$, $p>0.5$.

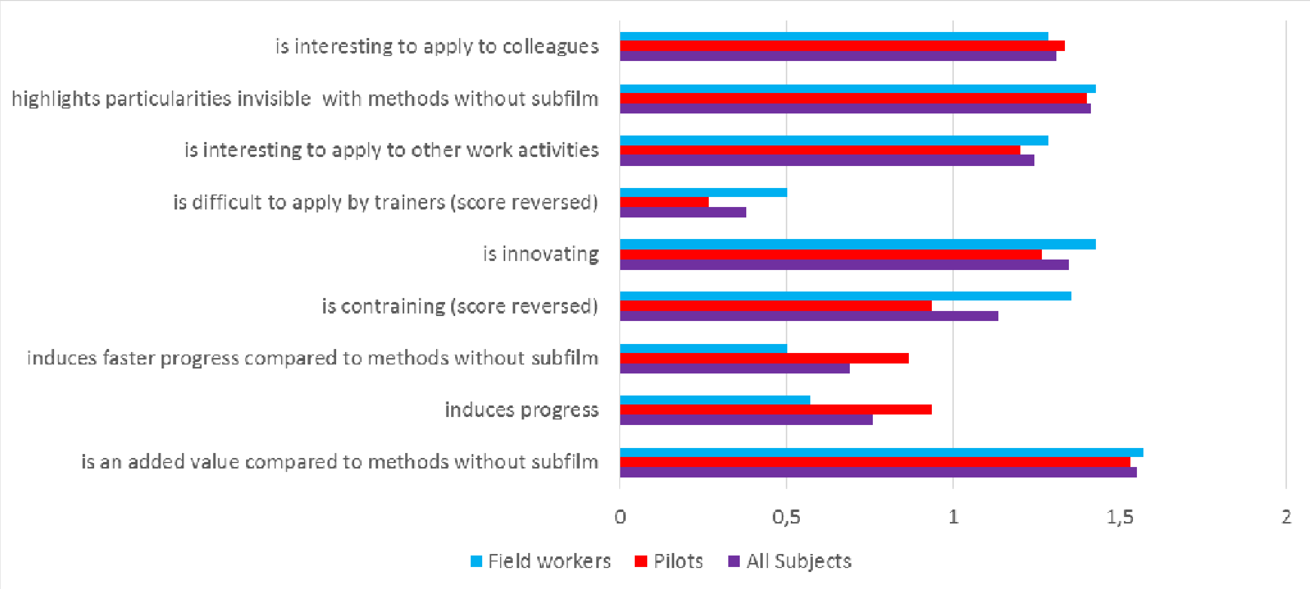


Figure 40: Average scores for each question evaluating SEBE/SPEAC method used for analysing activities during applicative test segment; assessment made by pilots and field workers.

The applicative test segment and the collaborative dimension of activities

Collaborative dimension was assessed according to criteria and properties summarized in Table 4 and Table 5. On the right column, Table 22 identifies the criteria of the left column which were systematically observed and validated through replay interviews (noted "Systematically Observed") and these which varied from on situation case to another (noted "Variable").

When compared with Table 4, Table 22 shows that all situation cases were of cooperative form and none of competitive form. The object of work was always stable and the means were not stable in only one case when the field worker encountered a problem as he made a mistake whilst identifying a piece of equipment.

Table 22: Criteria describing collaborative activities elaborated from the literature review and observed in the applicative test segment.

Criteria	Observations
Several subjects are involved.	Systematically Observed
Subjects are related by organizational relations.	Systematically Observed
Subjects are related by timelines (defined by beginning and end).	Systematically Observed
Subjects share the general mutual goal related to this task	Variable
positive correlation between the individuals' goals	Systematically Observed
negative correlation between the individuals' goals	Systematically Observed (reversed)
subjects aim at performing together the same task (commitment to the joint activity)	Systematically Observed
mutual responsiveness (A needs B and B wants to respond and vice versa)	Systematically Observed
commitment to mutual support (A needs B and B can respond and vice versa)	Systematically Observed
Subjects coordinate their actions	Systematically Observed
Subjects communicate	Systematically Observed
Means are stable	Variable
Object of work is stable	Systematically Observed
A system providing the organizational relations can be identified	Systematically Observed
Subjects act within this system	Systematically Observed

All these criteria were assessed through viewing the subfilms (what they exchange) and through replay interviews (what they explained about what they did of the exchange). The assessment by the PhD researcher was binary and coded 0 if not effective and 1 otherwise.

Criteria systematically observed (thus being equal to 1 or to 0 exclusively for all situation cases) could not be used for correlation calculation with others as they were equal for all situation cases (their variance being 0, the calculation of the correlation coefficient would imply dividing by 0). Therefore, only variable criteria were used for correlation analysis:

- Subjects share the general mutual goal related to this task,
- Means are stable.

Table 23 gives the same than Table 22 for the properties.

Table 23: Properties characterizing collaborative activities elaborated from the literature review and observed in the applicative test segment.

Identified properties	Observations
Subordinate type (organizational aspect)	Systematically Observed
Subordinate type (factual aspect)	Systematically Observed
Synchronous real time	Systematically Observed
Task-load asymmetry	Systematically Observed
Disturbance symmetry	Systematically Observed
Remote activity	Systematically Observed
Actions feedback immediate/deferral	Variable
Actions feedback symmetry	Systematically Observed

Table 23 only gives one item of interest for correlation calculation.

In addition to these criteria and properties, the matrix obtained when applying the SEBE/SPEAC method to the collaborative activity of pilots and field workers (see appendix, from 14 to 21) suggested that certain professional practices might be source of performance as mentioned just above:

- The workers structure their activity and also the sequence of reasoning and gestures.
  This aspect was assessed through viewing the subfilms. When it was effective, the subfilm showed that the worker did not look for what he had to do, his actions flowed smoothly, and his gestures were accurate. Conversely, when it was not effective, the worker was having many breaks to re-read the MO, was coming back to an action already done or coming back to a place where he already had done what to be done. The structuration of the activity was assessed by the PhD researcher based on the statement “the activity is structured” on a Likert scale coded from –2 (strongly disagree) to +2 (strongly agree). Observations showed that pilots always structure their activity; the dimensioning factor was thus the field worker.
  This item was labelled “field worker structures his activity” in the following.
- The field worker undertakes an overall or final control of the activity or of an activity phase before moving onto another phase.
  This aspect was assessed through viewing the subfilms. It was only assessed for the field worker as, for the types of collaborative activity observed, the pilot’s contribution on this aspect was difficult to assess with accuracy. The assessment by the PhD researcher was coded 0 if not effective and 1 otherwise.
  This item was labelled “field worker undertakes a final control” in the following.
- The workers share the same mental representation of the up-coming activity before performing the activity.
  This aspect was assessed through viewing the subfilms (what they exchange) and through replay interviews (what they explained about what they did of the exchange). The assessment by the PhD researcher was coded 0 if not effective and 1 otherwise.
  This item was labelled “share the same mental representation of the up-coming activity” in the following. This item was considered as an assessment of the aforementioned

characteristic "Subjects share the general mutual goal related to this task" according to the concept of "collective subject" in collaboration (see Lahlou et al. 2004 and section II-4-3-a).

- The workers share their forthcoming respective contributions before performing the activity (projective perspective-taking).
  This aspect was assessed through viewing the subfilms. It was easily objectified by the PhD researcher: when workers exchanged with their colleague about what they intent to do, this aspect was considered effective. The assessment by the PhD researcher was coded 0 if not effective and 1 otherwise.
  This item was labelled "share their forthcoming respective contributions" in the following.
- Both workers have time to read the MO before being involved in a co-preparation or a PjB with the pilot.
  This aspect was assessed through viewing the subfilms and most often through replay interviews as workers did not think to switch on the recorder early enough. The assessment by the PhD researcher was coded 0 if not effective and 1 otherwise.
  This item was labelled "workers pre-read the MO" in the following.
- The workers undertake a co-preparation or a PjB before performing the activity.
  This aspect was assessed through viewing the subfilms and replay interviews. The assessment by the PhD researcher was coded 0 if not effective, 1 in case of co-preparation or PjB and 2 in case of co-preparation and PjB.
  This item was labelled "Co-preparation or a PjB" in the following.

A last factor was noticed: the fact that the worker might be novice regarding the activity (in French: "primo-intervenant"): even when experienced, it might happened that the worker had never performed the activity. However, this parameter was not retained as relevant as only 1 out of 30 workers (pilots and field workers) was novice and this did not impact the other factors as showed by the mean values of assessments and by the correlation calculation.

It must also be noticed here that a factor suggested by the participants was not selected: the workload. As exposed in section III-1-1-c, two periods were investigated regarding the Operations shift teams activities: a period of low workload without outage of nuclear units and a period of high workload during unit outages. Whilst undertaking analyses with shift teams during the first period, participants insisted for experiments to be carried out during outage in order to observe how it might (not) work when the workload increases. The collected data did not presented any influence of this type of workload.

To summarize, the items being assessed were:
For the characteristics:

- Subjects share the general mutual goal related to this task, done through the above item "share the same mental representation of the up-coming activity",
- Means are stable,
- Actions feedback immediate,

For the properties:

- field worker structures his activity,
- field worker undertakes a final control,
- share the same mental representation of the up-coming activity,
- share their forthcoming respective contributions,
- workers pre-read the MO,
- Co-preparation or a PjB.

These items were assessed on the binary scale: 0 if not effective, 1 otherwise.
Also job performance and the proportion of direct and meta perspectives (DP and MP) respecting the intersubjective structure of (non-)collaboration at specific moments of the situation cases were assessed:

- job performance on a 1-5 scale, labelled "job performance" in the following,

- proportion of DP and MP respecting the intersubjective structure of (non-)collaboration on a continuous scale 0-100%, labelled "proportion of coherent perspective-taking" in the following.

These was done as suggested through the literature review and described in section III-1-1-d.

Due to limited time for replay interviews, all the specifics moments regarding the analysis of the intersubjective structure of (non-)collaboration identified during the pre-analysis phases could not be systematically discussed with subjects: N_{smom}=47 specific moments for the $N_{situ/app/coll}$ cases were discussed in replay interviews. These which were discussed were distributed over the different phases of the activities as described in the second column of Table 24. The third column provides the proportion of moments with coherent DP-MP between workers (as described in section II-4-3-b) out of the number of specific moments per phase. The right column provides comments regarding the values obtained. Figure 41 gives an insight of what was a specific moment by placing side by side an excerpt of a pilot's subfilm (left) and an excerpt of a field worker's subfilm (right).

Figure 41: Insight of a specific moment placing side by side an excerpt of a pilot's subfilm (left) and an excerpt of a field worker's subfilm during the pre-job briefing phase of the activity.

Table 24: Distribution of the specifics moments for intersubjective structure assessment over the activity phases.

Activity phase	**% of specific moments of the phase compared to $N_{smom(*)}$**	**% of moments with coherent DP-MP within the nb of specific moments of the phase**	**Comments**
PjB or Preparation	29.8	64 3	This phase always summons co-workers in a face-to-face exchange.
Realization with face-to-face communication in progress	6.4	33 3	All situation cases were remote activities; the realization involved very few face-to-face moments.
Realization with remote communication in progress	34.0	75.0	
Realization without communication in progress	25.5	50.0	
Debriefing	4.3	100	This phase did not often happened or was difficult to discuss in replay interview due to time left per interview.

(*)N_{smom} is the total number of specific moments.

Overall, during the replay interviews, 234 DP or MP were questioned and subjects evoked 34 different reasons to justify their DP and MP. The reasons being evoked several times for a few DP or MP, the total number of evocations was equal to 246. Table 25 gives the percentage of evocation of the main reasons per category of DP or MP: when a reason is evoked n times to explain the DP of collaboration for which the total amount of evocations of reasons is equal to N, then the percentage is n/N. This mode of calculation was chosen for the percentage to be comparable from one category of DP or MP to another; for example, if the subjects have given N=100 reasons to explain why they think they work with their colleague (DP of collaboration), some of them evoked "coordination of the following" as a reason explaining this, the sum of which being n=17 times leading to 17.0%.

Table 25: Percentages of evocation for the main reasons related to subjects' direct perspective (DP) or meta perspective (MP).

Perspectives	DP of collaboration	MP of collaboration	DP of non-collaboration	MP of non-collaboration
Reasons (%)	●Exchange of information (23.6) ●Coordination of the following (17.0) ●Joint involvement in the same activity (14.2) ●Mutual need (7.5)	●Exchange of information (18.8) ●Coordination of the following (15.3) ●Joint involvement in the same activity (15.3) ●Colleague's need (14.1) ●Mutual need (7.5)	●Perception of autonomy (35.1) ● Other activity in progress (18.9) ● Just reporting information (13.5)	● Other activity in progress (33.3) ●Perception of autonomy (27.8)

NB: The total amount per column is not 100% because we presented here the main reasons; other reasons are distributed with low percentage and are not worth to be mentioned.

It is remarkable that, among 34 different reasons, the same main reasons were almost always given for the DP and MP, for both collaboration and non-collaboration.

It is also interesting to analyse how the reasons evoked by the subjects match the criteria defining collaboration and properties, bearing in mind that collaboration was of cooperative type in this case (according to Table 4 and Table 5). Table 26 and Table 27 provide elements of analysis by presenting associated reasons (and related percentage) to each criterion and each property. When no reason corresponds, this may be due to the fact that the criterion is implicit (e.g. "several subjects are involved" is obvious) and/or because no reason was evoked that matched the criterion or the property. In the first case, it is written "Implicit" and in the second case it is written "Not evoked". When the item does not concern the activity, it is written 'None".

First it is remarkable that all the reasons evoked address the interactions between co-workers and none addresses all that concern the system or its organization.

Second, criteria that make collaboration effective for the subjects are hierarchized. Here is a list from the most important to the less, with two associated percentages given between brackets calculated from Table 26 by summing the contribution of the reasons associated with a criterion for DP and MP of collaboration:

- Subjects communicate (33.0% ; 23.5%)
- Subjects share the general mutual goal (24.5% ; 20.0%)
- Subjects coordinate their actions (17.9% ; 16.5%)
- commitment to the joint activity (14.2% ; 15.3%)
- mutual responsiveness (14.1% ; 21.6%)
- commitment to mutual support (9.3% ; 12.2%)

Table 26: Criteria describing collaborative activities elaborated from the literature review and assessed during the applicative test segment.

Criteria	Associated reasons for DP of collaboration (%)	Associated reasons for MP of collaboration (%)
Several subjects are involved	Implicit	Implicit
Subjects are related by organizational relations.	Not evoked	Not evoked
Subjects are related by timelines (defined by beginning and end).	Not evoked	Not evoked
Subjects share the general mutual goal related to this task	Exchange of information (23.6) Explanations (0.9)	Exchange of information (18.8) Explanations (1.2)
positive correlation between the individuals' goals	Mutual need (7.5) Worries about co-worker (0 9)	Mutual need (7 5) Worries about co-worker (3.5)
negative correlation between the individuals' goals	None	None
subjects aim at performing together the same task (commitment to the joint activity)	Joint involvement in the same activity (14.2)	Joint involvement in the same activity (15 3)
mutual responsiveness (A needs B and B wants to respond and vice versa)	Mutual need (7.5) Colleague's need (6.6)	Mutual need (7 5) Colleague's need (14.1)
commitment to mutual support (A needs B and B can respond and vice versa)	Mutual need (7.5) Worries about co-worker (0 9) Help available for co-worker (0 9)	Mutual need (7 5) Worries about co-worker (3.5) Help available for co-worker (1 2)
Subjects coordinate their actions	Coordination of the following (17.0) Task is coordinated (0.9)	Coordination of the following (15 3) Task is coordinated (1 2)
Subjects communicate	Exchange of information (23.6) Face-to-face communication (4.7) Phone communication (4.7)	Exchange of information (18.8) Face-to-face communication (1.2) Phone communication (3.5)
Means are stable	Not evoked	Not evoked
Object of work is stable	Not evoked	Not evoked
A system providing the organizational relations can be identified	Not evoked	Not evoked
Subjects act within this system	Not evoked	Not evoked

NB: Percentage calculated as for Table 25.

Table 27: Properties characterizing collaborative activities elaborated from the literature review and assessed during the applicative test segment.

Identified properties	Associated reasons for DP of collaboration (%)	Associated reasons for MP of collaboration (%)
Subordinate type (organizational aspect)	Implicit	Implicit
Subordinate type (factual aspect)	Implicit	Implicit
Synchronous real time	Task is synchronous (1.9)	Task is synchronous (2.4)
Task-load asymmetry	Related to non-collaboration	Related to non-collaboration
Disturbance symmetry	Not evoked	Not evoked
Remote activity	Implicit	Implicit
Actions feedback immediate/deferral	Real time report about the activity (3.8)	Real time report about the activity (3 5)
Actions feedback symmetry	Not evoked	Not evoked

NB: Percentage calculated as for Table 25.

The correlation calculation between characteristics, properties, transverse professional practices, perspective-taking and job performance are given in Table 28.

Table 28: Correlations *r* between parameters of interest regarding the collaborative dimension of activities during applicative test segment.

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Job performance	1,00										
2. actions feedback immediate	0,15	1,00									
3. workers pre-read the MO	0,52**	0,00	1,00								
4. field worker undertakes a final control	0,59**	0,10	0,00	1,00							
5. share their forthcoming respective contributions	0,61***	-0,26	0,78***	0,19	1,00						
6. means are stable	0,83***	-0,19	0,53**	0,38	0,68***	1,00					
7. novice	0,00	0,19	0,13	0,19	0,11	0,07	1,00				
8. field worker structures his activity	0,78***	0,32	0,42*	0,48*	0,42*	0,73*	0,18	1,00			
9. share the same mental representation of the up-coming activity	0,83***	-0,19	0,53**	0,38	0,68***	1,00	0,07	0,73*	1,00		
10. Co-preparation or PjB	0,67***	-0,15	0,65**	0,30	0,61***	0,63**	0,23	0,64**	0,63**	1,00	
11. proportion of coherent perspective-taking	0,66***	0,02	0,40*	0,20	0,13	0,45*	-0,10	0,52**	0,45*	0,45*	1,00

NB: *p<0.05 **p<0.01 ***p<0.001

Correlations involving socio-demographic data were not relevant: no significant correlation was found between subjects' professional experience and other factors; correlation with subjects' ages was not undertaken as they had been asked to give their precise ages but by ten-yearly periods (this was done so that the subjects did not to feel uncomfortable about giving their exact age but it did not differentiate the subjects significantly in his case).

Table 28 for variables correlation shows that:

- all items which address exchanges between co-workers are significantly correlated with job performance (variables #5, 9, 10, 11 vs variable #1),
- beyond items addressing exchanges between co-workers, variables regarding means, structure of the activity, final control and pre-read the MO are significantly correlated with job performance (variables #6, 8, 4, 3),
- "Co-preparation or PjB" of the activity (#10) might be favoured a pre-read of the MO (#10 vs #3)
- "Co-preparation or PjB" of the activity (#10) might facilitate "share their forthcoming respective contributions" (#5) and "share the mental representation of the up-coming activity" (#9) as related to significant correlations; for the same reasons, it might contribute to maintain stable the means (#6) and might contribute to help workers structuring their activity (#8).

Among all significant correlation coefficients for the item #11 "proportion of coherent perspective-taking", the highest is related to job performance: r=0.66 (p<0.00001). This suggests that co-workers having the same direct and meta perspective regarding working together also reach the highest job performance. Considering similar direct and meta perspectives whatever they are positive or negative appears to be the good choice: when considering similar positive (resp. negative) direct and meta perspectives only, i.e. co-workers think they work (resp. do not work) together and think their colleague thinks he works (resp. does not work) with them, the correlation coefficients with job performance are quite lower: r=0.42, p=0.029 (resp. r=0.30, p=0.127).

Multiple linear regression analysis was used to develop a model for explaining job performance (dependent variable #1 in Table 28) from relevant independent variables. Variables without variation were not retained as not relevant. Variable #7 "novice" having a null correlation with job performance was not retained as not relevant. Variable #10 "Co-preparation or PjB" was linked with variables #5 and #9 as observations showed Co-preparation or PjB were times for co-workers to favour perspective-taking and shared mental representations; this was confirmed by significant correlations between these variables. Variable #10 was thus rejected as not independent variable. Finally, the remaining relevant independent variables were #2, 3, 4, 5, 6, 8, 9 and 11. Multiple linear regression results are presented in Table 29.

Table 29: Multiple linear regression results for the eight-variable model explaining job performance.

	Coefficient β	Error	t-test	*p*
Constant	2,34	0,19	11,88	6,8E-06
11. proportion of coherent perspective-taking	0,25	0,10	2,34	0,051
4. field worker undertakes a final control	0,17	0,08	2,09	0,074
9. share the same mental representation of the up-coming activity	0,16	0,26	0,64	0,541
8. field worker structures his activity	0,15	0,07	1,94	0,093
5. share their forthcoming respective contributions	0,09	0,11	0,79	0,450
3. workers pre-read the MO	0,06	0,12	0,56	0,59
6. means are stable	0	0	#######	#######
2. actions feedback immediate	-0,195	0,09	-2,08	0,07

The results of the regression indicated the eight-variable model accounted for 96% of the variance (R^2=0.96, F(7,112)=14.45, p<10^{-10}). Analysis of residuals did not lead to reject any subject's contribution (Dixon's Q-test satisfied with a confidence of 99%) and their normal distribution was verified through a normal probability plot (correlation coefficient regarding the residual quantiles vs the expected quantiles was r(df=8)=0.96, p<0.001 with F(1,8)=1.27, p>0.29 implying that the null hypothesis of similarity for the distributions should not to be rejected and slope of the fit line was 1.11 showing a good agreement with the normal distribution).

It was found that four variables explained job performance among which three significantly:

- proportion of coherent perspective-taking: β=0.25, p<0.052,
- field worker undertakes a final control: β=0.17, p<0.075,
- field worker structures his activity: β=0.15, p<0.095.

Spearman's rank correlation coefficient ρ was calculated to assess how the relationship between job performance scores and proportion of coherent perspective-taking could be described by a monotonic function. In other words, we assessed if subjects were ranked similarly for each variable. We obtained ρ(N=15)=0.73 (p<0.002) illustrating a good match between ranking obtained on the two scales. In other words, job performance scores and the proportion of coherent perspective-taking statistically increased or decreased together. The results were confirmed with a Kendall's rank correlation coefficient: τ(N=15)=0.54 (p<0.005)[21].

To summarize results of section IV-1: The literature review led us to conclude that a model for competencies in action was necessary to answer RQ1 and provided only one model complying with these requirements, Le Boterf's model defining competencies as an interacting system of three poles, drawing competencies as a triangle: *Knowing to act, Wanting to act* and *Being able to act.*

[21] As a reminder:

- perfect agreement between the two rankings (i.e., two rankings are the same) gives τ=1
- perfect opposite agreement between the two rankings (i.e., two rankings are reversed) gives τ=–1
- perfect disagreement between the two rankings (i.e., no relationship between the two rankings) gives τ=0

After tests, the model revealed itself to be incapable of fully describing competencies in action. : the model could integrate some of the motives making subjects involved in action, those designed by external conditions.

This gave rise to the development of an innovative model, the Square of PErcieved Action model (SPEAC model) complementing the triangle of competencies with the fourth pole *Having to act*.

The SPEAC model was successfully tested (50 cases) and integrated in a protocol to access competencies in action: the SEBE/SPEAC protocol; it combined a first-person video recording of the activity followed by an in-situ subjective interview (replay interview). The protocol was tested for individual and collaborative activities at Chinon nuclear power plant in simulated situations (N=5 situations: valves maintenance, block-watch around in control room for a reactor pilot, equipment identification in machine room for a field worker and hydraulic configurations for a pilot-field worker collaborative activity) and in real operating situations i.e. during shifts with Operations teams (N=23 situations: hydraulic configurations, electric configurations, periodical tests and application of reliability practices).

For each work activity analyzed, the SEBE/SPEAC protocol showed significantly higher efficiency when compared with three other methods: higher number of explicit knowledge and know-how detected (from 1.44 to 17 times more), tacit knowledge and know-how identified while not detected with other methods and a reduction of the analysis cost by 30%.

Regarding analyses of collaborative activity, the concept of intersubjective structure of (non)collaboration was developed and applied on the basis of Gillespie's Intersubjective Theory. It was shown how perspective-taking was a crucial factor for the collaborative activity performance: significant high correlation performance with job performance and main factor to explain job performance through a multiple linear regression analysis.

IV-1-2 Discussion regarding elaboration and application of the SEBE protocol

The first section discusses the SEBE/SPEAC protocol performance and a second section discusses the collaborative dimension of the activities. This second section is necessary as the collaborative dimension of the activities took an unexpected importance in the study: when beginning the study, it was neither assumed that workers could perceived themselves not in collaborative activity when the organization provided a context for the activity to be collaborative, nor assumed that co-workers' perception could differ for a given activity.

IV-1-2-a The SEBE/SPEAC protocol performance

Knowledge, Know-How, Skills and Transference: application of the models

Figure 4 presented a model for the relationship between Knowledge, Know-How, Skills and Competencies aiming at suggesting a synthesis based on the literature review. The synthesis did not pretend to be the truth but a suggestion being a compromise appropriate to the present study. Nevertheless, the KKHS model was accepted on the basis of activity descriptions regardless the mode of learning. The following discusses the robustness of the model depending on the learning process used to elaborate competencies.

The SPEAC model is based on the subjects' perception of their competencies: this provides a subjective description of what makes and mobilizes the competencies. This may be altered by the recall process or incompleteness. This bias cannot be avoided as, according to the developments in section II-1, competencies may only be effectively observed in action which is underpinned by what the subjects have in mind, the recall of which is necessarily imbued with subjectivity.

Nevertheless, this bias can be lessened. The SEBE/SPEAC protocol relying on the first-person video recordings of competencies in action and as pointed out by Luff et al. (2013: 6.3) already mentioned in II-2-4, this approach may help researchers "to reveal how activities are produced with respect to the contingencies and circumstances of the participants within organizational settings, and examine how the technologies available in these domains are utilized". In parallel, the contribution of the analyst provides a distanced view on the activity: as for other methods (self or cross-confrontation, SAT method, description-based method), the confrontation of the subject and analyst's viewpoints contribute to lessen the subjective dimension of the collected material through questioning, one of the aims being to relate facts to the subjective descriptions.

However, depending on the goal of the analysis, it is not injudicious to apply the model on the unique basis of the subjective description of the activity, even if it is incomplete. For example, since the model is presented as describing the necessary conditions for the subject to put successfully competencies in action, any weakness of the structure described by the model applied to an activity highlights and contributes to understand the problem encountered. To illustrate this, let us consider a manager asking an employee to provide a work of quality (part of *Having to act*) and the same time, he limits the time affected to this work (part of *Having to act*). If this time is too short to ensure the required quality of the work, these two parts of *Having to act* are not coherent, giving contradictory injunctions and thus competencies cannot be put successfully in action. This incoherence within the pole *Having to act* makes it difficult to put competencies successfully in action. Applying the model to this situation helps the analysts to characterize the psychological issue for the subject, here incoherence within the pole *Having to act*. It also helps the analysts to try to find a possible solution to this issue: may the pole *Being able to act* provide compensatory resource in terms of means, by providing more performing tools for instance? Incoherence within the pole *Having to act* refers to a static approach and considering the interpolar relationship between *Having to act* and *Being able to act*, this refers to the dynamic approach and this short analysis is undertaken without the necessity to describing completely the activity or the competencies in action for this activity. In this case, the model is used as a tool that may provide a fast, objective and determinant identification of psychosocial risks and associated remedial measures (see an example of application in Fauquet-Alekhine & Rouillac, 2016c): indeed, the model can contribute to explain why, in certain occupational contexts, workers may experience psychological difficulties possibly or actually deteriorating their mental health.

In summary, the activity is associated with explicit components (actions, operations forming the trajectories towards the goals), and less explicit or even implicit components (motives, goals); for its accomplishment, the activity summons what the subject is implementing on intellectual and corporal sides to achieve the goals: competencies. Here, we support that action is therefore inseparable from competencies, whatever it is adapted or not to the situation, even when the subject has or not the good level of competencies, or whether or not the subject summons the appropriate set of competencies with regards to motives and goals. Thus, the activity can hardly be observed in a comprehensive approach and even less be analysed without considering the competencies in action. This point is in complete disagreement with some authors (Teulier & Girard, 2005: 4) who argue that "signs of activity may be observed and be analysed without using the concept of knowledge"; the fact is that if observation is possible, analysis without "knowledge" as part of competencies in action within the activity might be erroneous even though it is indeed possible. But only exploring it with the participants, by addressing KKSH, can validate whether or not such an analysis is erroneous or correct. That is one of the interesting aspects of this technique, and of SEBE in general, since it includes the exploration of whether the etic (by the subject) and emic (by the researcher) interpretations of the activity coincide (Lahlou, 2011).
Analysis of activity is therefore carried out through observation of the external components: actions and operations as well as the trajectories (chosen or avoided) towards the goals that shape largely summoned competencies. Operations being defined as subunits of the action (Zinchenko & Munipov, 1976; Leontiev, 2001/2006), our analysis must focus on the analysis of competencies in action, or action summoning competencies.

The subjects' perception of the SEBE/SPEAC protocol

A questionnaire (see appendix 8, questions 2 to 10 where "the studied RP" was replaced by "your activity") was used to assess subjects' perception of the SEBE method during the applicative test segment. The overall results showed a positive perception of the SEBE/SPEAC method both from the pilots and the field workers (Figure 40). The answers to the multiple choice questionnaire did not give reasons for these perceptions but spontaneous comments at ends of replay interviews (section IV-1-1-

d, § "The applicative test segment for RCE criteria") gave an insight of these reasons: they better understood what was done, they discovered bad habits like cutting off colleagues' speech, identified behaviours that should need corrections, were distantiated from the situation whilst viewing the sub-film thus providing a new standpoint; in addition to these personal benefits, it contributed to enhancing the collaborative work and helped them becoming aware of unconscious good practices.

When considering the distribution of scores per questions (χ^2(1,fd=8)=0.76, p>0.5) the perception was similar whether it be that of the pilots or the field workers. Even when there was a significant difference, the scores gave the same trend; for example, both pilots and field workers perceived the method as not constraining: the mean score was about 1 for pilots and about 1.5 for field workers.

The important points are that:

- They found the method interesting to apply to other activities as well as to colleagues: this suggests that the subjects identified the usefulness of the method. This assessment is thus not only that of the management or of the researchers.
- The overall perception was positive (in particular not constraining): this suggests that the method might be applied to anyone in the shift teams. However, this should be balanced with the fact that subjects participating to the research were all volunteers and that the study was presented as applying a method to identify the competencies of experienced workers. This induced a natural selection of participants: workers at ease with their profession enough to accept being exposed to the researcher through the replay interview had no difficulty to accept participating. It may be assumed that for workers less at ease or perceiving themselves "not competent" or "less competent" or having a problem of self-esteem would have given a feedback less positive.
- Despite the fact that the purpose of the method was to analyse the work activity for future enhancement of professional practices through training, subjects perceived their professional practices already improved during the replay interviews, especially pilots (mean score close to 1). This had already been noticed by researchers applying SEBE and involving subjects in replay interviews to analyse the work activities (see for example: Le Bellu, 2016: 22).

In addition to these visible aspects of the subjects' perception (visible through questionnaires or spontaneous talks), we may assume that, despite this was not said, the interest shown to subjects for their work activities was another positive point.

All these elements lead to assume that implementing widely the method throughout an industrial plant might not encounter objection from the workers.

Contribution of introspection in replay interviews

Could we try to implement introspection during interviews of the present study?

Regarding direct introspection, it was clear from the outset that it could not be implemented in our experiments: as developed in section IV-1-1-c, it was assumed that, to access tacit knowledge and know-how, workers' spontaneity of actions had to be preserved whilst performing activities; therefore, simultaneous verbalization (or concurrent verbal reports) were excluded from the present study (the shorter delay between activities and interviews being 1h30).

Regarding indirect introspection (or retrospective introspection), the implementation seemed difficult and demanding many precautions, therefore requiring too much energy compared to what could be potentially expected. Moreover, the delay between the possible introspected events and associated verbal reports were not several seconds, even not several minutes but several hours, hence much more than times reported in studies depicting indirect introspection conditions. Hence indirect introspection was not envisaged at the outset of the present study. However, the development above and the associated literature review suggested that replay interview might present characteristics of indirect introspection at given moments. We thus decided to undertake special analysis of replay interview recordings so as to determine whether replay interviews did not actually involve indirect introspection.

As we saw in the literature review, introspection as well as retrospection does not seem to be that easy to implement. In her studies addressing work activity analysis through subjective video-based interviews, Le Bellu (2011, 2016) mentioned introspection without developing its contribution to the analysis but another research team (Rieken et al., 2015) recently published this kind of study and explicitly referred to introspection in the title of the paper. According to Rieken et al. (2015: 256), "Introspection in digital ethnography does not rely upon a mental representation of events but instead on shareable digital account of events" in that it "gives both the participating introspecting subject and the inquiring interviewer equal access to the first-person perspective digital representations".

It can be agreed that introspection in digital ethnography relies on shareable digital account of events but, before reaching the "subject-analyst" sharing level, another level, prior to this mentioned by Rieken et al., must be considered: the "subject-subject" level. Indeed, during the replay interview (as for any self-confrontation using video), the first one concerned by sharing events is the subject him/herself. This is why self-confrontation is called "self" - "confrontation". This consideration suggests that the first part of Rieken et al.'s sentence might be wrong as the subject is confronted with events experienced in the past for which the first-person perspective of the sub-film summons mental representations of what happened at this time.

In other words, the SEBE approach (or digital ethnography approach) deconstructs Comte's argument saying that the subject "cannot split in two" because here, due to video self-confrontation, splitting the subject in two becomes effective. Indeed, if a lapse in time Δt separates the realization of the activity happening at time t and the replay interview, thus happening at time t+Δt, the context of the replay interview brings together the conditions necessary for submitting the subject's Self at t+Δt (noted $Self_{t+\Delta t}$) watching and subjectively re-experiencing a past activity that might give him/her access to the re-enactment of event experienced by the Self at t (noted $Self_t$). Hence, provided that the conditions of introspection are effective during the replay interview, the subject may undertake introspection by the $Self_{t+\Delta t}$ on the $Self_t$. As suggested by Clot (2001: 258) referring to Vygotsky, " 'being' does not coincide with the phenomenon (in other words, the 'real' with the 'realized') and even introspection does not abolish this difference. Because the mind is not only subject to it. It is divided into object and subject: my joy and my introspective understanding of this joy are different things" (pp. 273-274). Similarly, the $Self_t$'s event and the $Self_{t+\Delta t}$'s understanding of this event are two different things because they address two different processes (occurring and understanding) and it involves two different Selfs ($Self_t$ and $Self_{t+\Delta t}$). This proposal of multiple Selves was already envisaged by Overgaard (2006: 630): " 'The self' or the subject is obviously not identical to the content of his or her consciousness; for instance, the subject enjoys an uncountable number of conscious throughout his or her lifetime. Were the subject identical to conscious content, he or she would be as many selves as possible number of contents, continuously beginning and ceasing to exist."

All this helps us to assume that introspection by the $Self_{t+\Delta t}$ on the $Self_t$ might be possible during the replay interview. This assumption matches Rieken et al. (2015) writings; for them introspection effectively occurs during the self-confrontation interview when the subjects view subjective (first-person) recording of their activity. So how was this done in Rieken et al.'s study? The main problem with this work is that authors claimed using introspection and emphasized its social dimension, but they did not provide neither experimental evidence of that nor analysis of this process. Therefore, the contribution of introspection in Rieken et al.'s work and consequently of its social dimension remained at the stage of assumption.

The fact that the subject may undertake introspection by the $Self_{t+\Delta t}$ on the $Self_t$ provided that conditions of introspection are effective during the replay interview is fundamental. According to the literature review describing what these conditions may be (see section II-3-2), it is clear that if introspection happens during the replay interview, it is impossible to take place all along the interview since the interview is mainly a detailed explanation of states of mind, goals, intents and actions that goes beyond the mere description of the mental state. Introspection in replay interview might take place from time to time, it might even be said that it happens very infrequently and lasts very short length of time for each. Indeed, during the replay interview, the $Self_{t+\Delta t}$ (the subject watching the sub-film) comments and explains most of the time what is doing the $Self_t$ (the subject in action in the sub-film) relying mainly on episodic memory; this is neither introspection nor retrospection. If introspection happens, it is when the $Self_{t+\Delta t}$ provides a comment on the $Self_t$'s action whilst viewing the introspected event in the sub-film or immediately after viewing it, combined with the fact that this comment is short and gives information about a $Self_t$'s mental state or cognitive process about which neither the $Self_{t+\Delta t}$ nor the $Self_t$ are aware of before making the comment.

This description additionally shows that, if it is introspection, it is nevertheless different from that described in the literature review in the sense of the reviews of Overgaard (2006) and Danziger (2015): for these authors, introspection is an interaction by the $Self_t$ on the $Self_t$ whereas here the interaction is by the $Self_{t+\Delta t}$ on the $Self_t$. Instead of introspection (that we should name direct introspection for reasons of accuracy), in this case we had retrospective introspection (or indirect introspection as proposed by Titchener (1912: 491)) which is triggered by self-confrontation and not opposite as claimed by others (see Rieken et al., 2015: 260). As recalled by Kriegel (2013: 1172), direct introspection occurs simultaneously with the introspected event whereas indirect introspection occurs later and involves recollection of past events; therefore, in terms of memory (Figure 42), the former relates to short term memory (or working memory) when the latter relies on episodic memory (one of the forms of explicit memory) or procedural memory (one of the forms of implicit memory) used to recall past events (Piccinini, 2003).

Lahlou's analyses of replay interviews suggested that indirect introspection might be effective during replay interviews. He noticed that replay interviews could address events that could remain unconscious and could be remembered with accuracy : "as the human machine is designed for economy of attention, most of what we can do without cluttering our limited attention and consciousness span is done automatically (that is: often below the conscious threshold), and not stored in explicit memory" (Lahlou, 2011: 620); "Probably because the recordings contain rich situated visual, auditory and kinetic cues which evoke re-enactment, participants recall with great detail their mental states at the time they acted, and can verbalize them, including their goals and sometimes sensations (e.g. thirst) […]It seems that the more similar the context of memory retrieval is to the context of memory encoding, the better is the recall, and that having multimodal cues helps, especially when they are spatial or motor - see the enactment effect (Engelkamp & Cohen, 1991). In other words, re-living the situation from first-person perspective would facilitate recalling one's own actions and mental states/processes." (Lahlou et al., 2015: 5). What is recalled is better anchored in memory due to the fact that what is recalled was experienced in action involving both mind and body (see for example Engelkamp & Zimmer, 1989; Cohen, 1989; Engelkamp & Cohen, 1991; Engelkamp et al., 2005; Madan & Singhal, 2012; Schult et al., 2014). These considerations led us to form the hypothesis that a kind of indirect introspection might occur, a kind of long term indirect introspection involving shifted verbal reports not immediately consecutive to the introspected event but delayed by several hours; this might be called introspection provided that the introspected mental state could be recalled at the moment of the introspective act from a non-conscious memory.

Analysis of replay interviews confirmed the hypothesis that long-term indirect introspections effectively happened very few times and only lasted a very short length of time. Or should we say that we identified long term indirect introspection happening a very few times during a very short time each. This was detected when identifying a tacit knowledge or know-how. To illustrate this, let us come back to the example of the pilot Figure 34 describing his activity "block watch-around" in section IV-1-1-d (ref: TEST-IND-OP-01). This activity consists in watching and checking operating parameters on control panels of the control room.

[redacted]

Figure 42: The multi-store or modal model of memory (Atkinson-Shiffrin, 1968) is the model generally adopted by the scientific community (Velez-Pardo & Jimenez-Del-Rio, 2015). Memory is a three-stage sequence: Sensory Memory, Short Term Memory and Long Term Memory.

- Sensory Memory refers to the ability to retain sensory information through the five senses.
- Short Term Memory refers to the capacity to keep available information for a short period of time.
- Long Term Memory refers to the capacity to hold a large amount of information for a long period.
- Encoding process: the perceived item of interest is converted into a construct that can be stored, and then recalled later from Short Term Memory to Long Term Memory)
- Storage process: retaining information in either of the three-stage memory, but mostly in Long Term Memory
- Consolidation process: stabilizing a memory trace after initial acquisition
- Retrieval process: re-accessing events or information from the past previously encoded and stored
- Implicit Memory refers to memories storing previous experiences to perform of a task without conscious awareness of these (including Priming Memory, Procedural Memory and (non) Associative Learning Memory).
- Explicit Memory refers to memories that can be consciously recalled.
- Episodic Memory contains past personal experiences (e.g. time, places, and related emotions).
- Semantic Memory refers to meanings, understandings and other concept-based knowledge.

During the replay interview, to depict the way he was checking monitors whilst performing the activity, the pilot said “je regarde si ça tire droit” (I watch to see whether it goes straight). Consecutive exchanges between the pilot and the analyst showed that this meant the pilot did not read the values of parameters on the monitors: it was easier and faster to check a signal position rather than read the value according to the scale of the monitors and compare it with the expected values. He said this was done without losing any reliability on values. The post-analysis of the replay interview allowed us to

assuming an introspection occurrence when detecting a tacit knowledge during the subject-analyst interaction (illustrated on Figure 44) as described in the following:
(Ref File: interview replay OpJ 20130821 – file 1 Go)

- At t=18:09: Identification of specific moment for the $Self_t$
  While the subject (the $Self_{t+\Delta t}$) and the analyst were together watching the video during the replay interview, the subject (the $Self_t$) in the subfilm stopped in front of monitors on the control panel (see excerpt of the subfilm on Figure 43: the video field remained unchanged for a few hundreds of milliseconds), suggesting that the subject was looking at or thinking about something. The analyst asked what was going on (t=18:09) and the subject, who had his right hand on the mouse, stopped the video player (t=18:09).

Figure 43: Excerpt of the pilot's subfilm while the video field remained unchanged for a few hundreds of milliseconds during the activity "bloc watch-around". In the upper part of the picture, five paper monitors provide prints of physical parameters with time.
Source: Data subcam et al\simu pil MS1 & MSI-062013\20130606 part1 (Op J) – file 1 Go – t=07:54

- At t=18:10: Verbal reports by the $Self_{t+\Delta t}$ about the $Self_t$ to qualify the specific moment (from t=18:10 to 18:12)
  The subject said "je regarde si ça tire droit sur les enregistreurs" (I look to see whether it draws straight on the recording monitors).
- At t=18:12: Verbal reports by the $Self_{t+\Delta t}$ about the $Self_t$ to spontaneously explain the specific moment (from t=18:12 until t=18:14)
  Continuing the first comment, the subject spontaneously gave details about the physical quantities monitored.
- At t=18:26: Verbal reports by the $Self_{t+\Delta t}$ about the $Self_t$ to explain the specific moment (from t=18:26 until t=20:14) when answering questions
  The analyst took notes and then asked (t=18:26) what he meant by the expression "goes straight". The pilot explained (t=18:34 until 18:54) of goal of this way of working: he did not read the values of parameters for certain monitors or indicators; it was easier and faster to check a signal position rather than read the value according to the scale of the monitor and compare it with the expected value. Further questions and answers (after t=18:54 until 20:14) showed that this was done without losing any reliability on values. When he was asked whether this practice was his own, the subject said that most of his colleagues (even all) did so. When he was asked where he was taught this practice, he could not find any answer.

a [redacted] [redacted] b

c [redacted] [redacted] d

Figure 44: Sequences of replay interview including introspection.
a)t=18:09 - the subject stopped the video player showing the specific moment (subject's mouth is closed)
b)t=18:11 - the subject qualified the specific moment (subject's mouth is opened)
c)t=18:14 - the subject spontaneously gave details about the specific moment
d)t=18:37 - the subject explained the specific moment (with gesture)

In the light of the literature review, we suggest that introspection effectively happened in this example in its indirect form and followed a process made up of two distinct steps:

- A focus of the subject $Self_{t+\Delta t}$ on a given mental state triggered by the analyst corresponding to the previous step "Identification of specific moment for the $Self_t$ " at t=18:09.
- A self-description of the mental state by the subject $Self_{t+\Delta t}$ through an immediate, consecutive brief verbal report corresponding to the previous step "Verbal reports from the $Self_{t+\Delta t}$ about the $Self_t$ to qualify the specific moment" from t=18:10 to 18:12

This two-time segment (identifying and qualifying) fulfils Gaillard's criteria described in section II-3-2 of the literature review necessary for introspection:

- Instructions given to subject for verbalization were short (what was going on ?) and we may assume it did not have any effect on the introspected cognitive processes: the verbal report was neither limited to a few possible categories such as ''yes'' or ''no'' nor forced to be an elaborated and exhaustive description or the introspected even.
- Despite its metaphorical form, the verbal report was informative enough to be considered as complete regarding the subject's own cognitive processes. It was verbalized as simply as possible and thus minimized the disturbance of the current cognitive process in progress.
- The verbal report was consistent with the third-person observation and analysis of the video undertaken by the analyst.

However, the indirect introspection was shifted in time by several hours when compared with the task carried out with (average delay (in hours) which was M=59.1 with SD=39.6) and thus did not comply with the maximum 5 second-criterion suggested by Ericsson for verbal reports (see section II-3-2 and Ericsson, 2003). We now aim to demonstrate that, despite this non-compliance and thanks to the use of replay interview method, we nevertheless had indirect introspection. This is provided by a detailed analysis of what happened during this two phase segment (identifying and qualifying) and after.

- "Identification of specific moment for $Self_t$ " at t=18:09
  Focus of the subject $Self_{t+\Delta t}$ on a given mental state triggered by the analyst.
  This first introspective phase was the identification of the mental state. This was triggered by the analyst's question because the action going on at this moment on the sub-film was just a usual action in the subject's opinion. This is why the subject neither stopped the video by himself nor made any spontaneous comment. Whilst watching the video, the subject probably re-enacted the activity due to "situated visual, auditory and kinetic cues" contributing to "recall with great detail their mental states at the time they acted" as suggested by Lahlou et al. (2015). We may suggest here two hypotheses regarding the cognitive process underpinning this identification: i) the re-enactment effect recreated the same unconscious mental state for the subject whilst viewing the sub-film and the mind was made conscious at the moment of the analysts' question, ii) the analysts' question summoned the subject's implicit memory storing previous experiences to carry out a task without conscious awareness of this (see Figure 42), i.e. the procedural memory. Whatever the hypothesis explaining the process, it is highly likely that the mental state identified was unconscious for the subject before identification.
- "Verbal reports from the $Self_{t+\Delta t}$ about the $Self_t$" to qualify the time segment t=18:10 to 18:12
  Self-description of the mental state by the subject $Self_{t+\Delta t}$
  The subject said "je regarde si ça tire droit sur les enregistreurs" (I watch to see whether it draws straight on the recording monitors). The metaphorical expression used for this immediate consecutive verbal report was natural, simple, and contained all the information necessary to depict the mental state, thus minimizing the disturbance of the current cognitive process (Titchener, 1912; Ericsson, 2003; Danziger, 2015). The problem here was that "all the information necessary to depict the mental state" was concentrated and "hidden" within this simple metaphorical verbal report.

This two phase segment was then complemented by an explanation phase:

- Verbal reports from the $Self_{t+\Delta t}$ about the $Self_t$ for explanation after t=18:12
  At this point, the indirect introspection was completed and the subject entered a post-introspective phase: the introspected mental state had become conscious and the subject was definitely engaged in a cognitive process of description. This phase relied on procedural memory to describe the metaphorical introspective verbal report and relied on episodic memory when the subject gave details regarding the parameters checked, the context of checking and the subject's goals (Figure 42).

This kind of long term indirect introspection might have happened several times per interview. They were so short (here not more than 3s.) that they have gone unnoticed: we may assume that most of the detection of tacit knowledge or tacit know-how went through such process. An exhaustive analysis of all replay interviews was not carried out to count these events because not bringing any added value for the PhD thesis; nevertheless, it might be interesting to undertake it for an extended study.

Subtleties of application of the SEBE/SPEAC protocol

The SEBE/SPEAC model-based method draws strength mainly from the subjective video-based interview, the sequenced questioning, and the Grounded theory approach.

As discussed in many parts of the present dissertation, using a subjective video combines the advantage of recalling the actions through the video and the advantage of a recall from a first person perspective. This has already been argued and will not be re-discussed here.

The benefit of sequenced questioning has also been argued in many parts of the present dissertation and will be not re-discussed here. However, experiencing the SEBE/SPEAC protocol in the experimental and applicative segments for total number of 21 situations showed that, in practice, the protocol works differently for some points than what had been assumed theoretically when elaborating the protocol.

In theory, the access to knowledge or know-how is supposed to be favoured by the replay subjective and goal-oriented approach of the interviews. In practice, this was verified in the present study (the results demonstrate it) and demonstrated by Le Bellu before (2010, 2011). Regarding this point, theory and practice converge.

In theory, the access to tacit knowledge or know-how is supposed to emerge from the comparison between the answers given by the subjects during the first sequence of the interview (questioning the poles *Having to act* and *Knowing to act*) and the following sequences. The access to tacit knowledge is thus supposed to emerge from a rational comparison: it was assumed that what is said in the following sequences but not said during the first sequence might be considered as tacit. Strictly applying such a rule would lead to identifying a lot of explicit knowledge and know-how as tacit while they are explicit. This is due to the fact that, whatever the time spent carrying out the first sequence and even when using a large panel of indirect questions, subjects cannot recall all that is explicit to them or do not mention what is obvious in their opinion; for example, knowing how to handle a valve in order to close it may not be discussed whereas some valves close the other way round to others. The difficulty here is exactly the same as for the SAT method: in this first sequence, no video support is used. Consequently, in practice tacit matter emerges throughout the course of the interview, especially during the sequence when the subjective video is viewed. It is then the analyst's duty to be shrewd enough to seize clues during the exchange that suppose the identification of a tacit knowledge and know-how and to re-question at this moment the poles *Having to act* and *Knowing to act*. This shows all the importance for the analysts constantly to keep in mind the polar structure of the SPEAC model during the interview. The post-analysis of the recorded interview allows the analysts to identify and differentiate tacit from explicit. However, the work is not completed. The tacit matter is labelled as "possible": indeed, what is identified as "tacit" by the analysts during post-analysis might be elements considered by the subjects as basic knowledge (the trivial fundamentals of the profession) and for this reason, the subjects might not have spontaneously mentioned them. This is why the restitution-validation phase is so important: it is the moment for the analysts to present and discuss the output matrix to the subjects and validate the matter identified as well as their respective status: explicit or tacit. Only the professionals concerned can decide on the issue.

Performance of the SEBE/SPEAC protocol

Before discussing the performance of the SEBE/SPEAC protocol compared with other methods, it must be pointed out how the efficiency of the SAT method was overestimated in terms of cost. In section II-3-3, it was explain how the SAT method was an iterative process: when an activity is analysed at the national level of EDF SA, the corresponding results may be improved by a new analysis on a plant of the nuclear fleet, and again on another plant. The objective of this is to encourage improvement in the professionalization strategy regarding the analysed activity by adding/removing some parts of the related training, and improve training through suggestions. Therefore, one activity is analysed several times, up to 21 if all possible levels have contributed to the activity analysis, which is always the case. This is why, in section IV-1-1-d, the time spent for each activity analysis was estimated as follows: at each level (national or local), 5 to 10 professionals gathered around a table spending about half an hour per activity; to achieve the process completely, at least 2.2 to 4.4 man-days are necessary ((5 to 10people) x (20 sites+1national) x (½)/24h)=2.2 to 4.4). For the calculation, we took the minimum possible value of 2.2 man-days. This was a first approximation in favour of the SAT method. The second approximation in favour of the SAT method lied in the fact that, when the results are used in a Training Centre, most of the time they are reconsidered through a new analysis by the trainers just before application to design a training session; this additional time was not counted. The cost estimated for the SAT method was finally clearly underestimated. Conversely, time spent for the self-confrontation method and for the SEBE/SPEAC method was calculated as close as possible to its real value. In spite of these approximations, the SAT method remained more expensive.

The comparative analysis between the SPEAC method and other methods both in the experimental test segment and the applicative test segment (results in Table 20 and Table 21) showed that the former better described the reference situation (as defined by Samurçay & Rogalski (1998), Figure 13) It was thus better adapted to elaborating the input data necessary for the design of a relevant training session.

In addition, the design of the SEBE/SPEAC resulting matrix suggested that two key factors might strongly contribute to the improvement of the training session design. The first key factor relies on the higher number of the knowledge and know-how identified (including tacit) compared with other methods (this difference will be discussed in the next paragraph). This suggests that the contribution of the SPEAC method is more efficient from the outset. The second key factor is that the matrix provides a series of fields of competencies associated with the activity analysed; this helps the training designer to elaborate easily the scenario according to the field of competencies that must be worked with trainees.
To illustrate this statement, here is a simple example: when considering the Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Application of Reliability Practices" regarding Cross-Control (CC) in appendix 13, the description of the field of competencies labelled "Gather the necessary conditions to the effectiveness of the RP" suggests that these competencies must be mobilized in a work situation summoning two interactants; therefore, a relevant training session cannot be envisaged as individual and the interactant must be played by another trainee or by the trainer. In using this property of the Outcome Matrix, the simulated situation gains in relevancy. The reflexive analysis taking place during the training session debriefing subsequently gains in relevancy too. When discussed in the light of the Experience Learning model of Kolb (see Figure 12; Kayes, Christopher-Kayes & Kolb, 2005), improving the concrete experience by improving the simulated situation contributes towards enhancing the following reflexive observation: this reflexive observation is oriented to a concrete experience which starts from a situation of reference and is prolonged in the simulated situation, the debriefing of which allows trainees to be engaged in a distantiated analysis of what they experienced in this situation. This reflexivity results in an overall higher performance. However, this can only be achieved provided that the debriefing of the simulated situation experienced is correctly conducted (see about this point Issenberg et al., 2005; Fanning & Gabba, 2007; Anderson et al., 2012; Fauquet-Alekhine & Boucherand, 2016b).

The better efficiency of the SEBE/SPEAC model-based method may be due to the effective efficiency of the model and protocol; it may be also due to the intrinsic limits of the self-confrontation, the SAT method and the SAT method combined with a description-based method.

Analysing the application of the self-confrontation mainly shows that, conversely to the SEBE/SPEAC model-based method, the interview is not structured on the basis of a *sequenced* questioning leading to highlight tacit knowledge. Applying the SEBE/SPEAC model-based protocol, analysts keep in mind the four poles of the SPEAC model all along the course of the interview (orienting or provoking relevant questions) as well as during the post-analysis of the interview. This helps analysts to remain aware of what kinds of clues have to be found.

Analysing the application of the SAT method applied within the framework of the "Competencies Program" in the EDF nuclear fleet highlighted the following points:

The action program "Competencies Program" (EDF, 2013) was launched for the whole fleet at national level, the objective being the improvement of the professionalization strategy regarding the analysed activity by adding/removing some parts of the related training specifications and to improve training through suggestions. The fact is that in 2014, the problem remained unsolved. Among causes, the analysis undertaken in the frame of the present PhD (Fauquet-Alekhine, 2014b) regarding the way the Competencies program works showed that:

i) it does not address any in-depth questions regarding what constitutes the competencies of experienced workers,
ii) asking experienced workers to be more involved in the training sessions in training centers is vain as there is obviously a great need of such workers in the teams,
iii) in practice, very few "Training commissions" are organized and when it is the case, the analysis is far from being in-depth,
iv) some tools have been developed on the basis of new Information & Communication Technologies but diffusion is inefficient (for example, no applications available at Chinon NPP)

and they require high tech computers which are expensive and for which NPPs do not want to spend money (for example, at Chinon NPP, only two computers for more than 1200 people).

Regarding the difficulty pointed out in (i), the main difference between the SAT method and the SEBE methods in general relies on the form that the analyses take: around a table in a room for the SAT, in the field through first-person videos for the SEBE. This may be analysed by referring again to the comments of Luff et al. (2013: 6.3) already mentioned in II-2-4, highlighting that video analysis may help researchers "to reveal how activities are produced with respect to the contingencies and circumstances of the participants within organizational settings, and examine how the technologies available in these domains are utilized". Without the help of the subjective video, the probability of reaching in-depth levels of knowledge and know-how is lower.

This difficulty might perhaps be lessened by applying the explicitation interview technique (Vermersch 1994) but people conducting the meetings in the framework of the SAT are not trained for it and furthermore the meeting context is anyway not adapted to applying this technique.

In addition, reading and analysing the resulting outcomes from the SAT method showed that:

- The collective dimension of the activities was barely addressed leaving aside about 15 to 50% of the competencies when referring to the present study.
- The non-technical skills were not considered: the analysts seemed to focus on technical aspects of the activities.
- The tacit competencies could not be reached leaving aside at least up to 70% of the competencies (assessment done from Table 20 and Table 21).

This obviously resulted in an underestimation of the competencies and a far from exhaustive identification.

Regarding the SAT method combined with a description-based method, the difficulty (i) pointed out above remains: adding a stage of analysis when applying a description-based method results only in adapting the conclusions of the SAT method to the forthcoming trainees' needs. This is due to the fact that the description-based method works like the SAT method: around a table in a room rather than in the field. Again, the difficulty might perhaps be lessened by applying the explicitation interview technique but people conducting the meetings are not trained for it and the meeting context is not adapted for applying this technique anyway.

These findings lead to:

- the confirmation that a method that does not imply the use of a first-person video is obviously less efficient than a SEBE method (i.e. the SEBE/SPEAC method is obviously more efficient than the SAT method),
- the hypothesis that the SAT method might be applied with more efficacy if more close to the field,
- the application of the SPEAC-based protocol provides a more exhaustive analysis.

These points are now discussed considering the nature of the knowledge and know-how identified throughout the methods.

First, the knowledge and know-how identified through the SAT methods remain individual and technical: it seems that the analysts applying the SAT-method focused on technical skills and were not aware of the possible existence of the collective aspect of skills. This point is well illustrated by the facts that

i) rare collective knowledge or know-how may be read in the database provided by the SAT-method application (whatever the activity is) and

ii) for example the database provides data for cell lockout of electric or hydraulic configurations regarding the field worker but not for the pilot whereas the relationship between them exists and has been observed and characterized during the applicative test segment of the present study. These aspects contribute to diminishing the number of knowledge and know-how identified by the SAT method.

Second, in contrast to to the SEBE methods which may access tacit knowledge or know-how throughout simultaneous verbalization to actions (Lahlou, 2011; Le Bellu & Le Blanc, 2012; Lahlou et al., 2015; Le Bellu, 2016) or through SPEAC-based questioning (the present research), the SAT protocol is not designed for this, thus reducing from the outset the amount of knowledge and know-how identified for an activity. The issue is different when the SEBE/SPEAC method is compared with the self-confrontation (Table 20): both were first-person-video-based but despite of that, the SPEAC protocol identifies more knowledge and know-how. The only significant difference is the protocol adopted to conduct the interview; therefore, it is legitimate to assume that the SPEAC-based sequenced questioning makes the difference.

Following this second point, one may suppose that accessing tacit knowledge contributes to making the SPEAC method more efficient in terms of number of knowledge and know-how identified. Data in Table 20 and Table 21 (pages 123 and 124) shows that it is not the case: explicit knowledge and know-how are more numerous with the SPEAC method than with other methods.

The proportion of tacit knowledge and know-how varies from 17.7% to 66.6% and more than half of these percentages are higher than 50%. On the overall, the proportion of tacit knowledge and know-how might be found high. In fact, it is coherent when compared with the literature: Faust (2007), considering work activities in nuclear industries, claimed that the contribution of tacit would represent about 80% of the overall knowledge and know-how. Nevertheless, other experimental studies showed that this proportion could vary depending on the task: from 5 to 95% for work activities related to innovative pedagogical practices using technology (Anderson, 2004). Khosrow-Pour (2008: 350) illustrated it by comparing riding a bicycle summoning knowledge among which most is tacit and processing a claim for travel expenses in an organization summoning knowledge among which most is explicit. The former case summons a high contribution of tacit while the latter requires a high contribution of explicit. The present study confirms this comment: for simple activities requiring less reflection, the proportion of tacit is the lowest (21.4% for Alarm treatment and 17.7% for Application of RP) and for the most complex activities analysed, the proportion is the highest (about 55% for hydraulic configuration in ROS, electric configuration and periodical test).

Hence, when on the one hand validating that activities analysed require a high proportion of tacit knowledge and know-how and when, on the other hand, objectifying that the SAT method does not provide any data regarding this aspect of competencies, we may question the relevancy of the method. Yet it works! Indeed, until now, professionals on French NPPs have been operating nuclear units with satisfactory achievement: electricity is produced and there are no major safety issues. This means that, until now at least, the system has included some compensating mechanisms that have helped workers acquire and develop the necessary tacit knowledge and know-how.

In the past years, as described in Chapter I, this was essentially provided by tutorial and mentoring periods. However, to date, with the social phenomenon of "skills drain" (retired workers leave the companies *en masse* sometimes even before the recruitment of newcomers) impeding mentoring (section I-3), these "compensating mechanisms" may not be as efficient as in the past years. At the same time, the average duration of experience has decreased for both professions, pilot and field worker, moving from about 15-20 years to about 5 years. In these conditions, it is clear that today's experienced workers do not pass on their expertise to novices as experienced workers did in the past. At least two hypotheses might explain why "Yet it works!" The first is that the dynamic of the phenomenon is long lasting and issues remain latent. The second is that, in the recent years, the company has adapted its organization regarding shift teams. One unit-pilot (described in footnote 10 page 76, section III-1-2-d) has reinforced the pair of operator-pilots which was in charge of operating a nuclear unit from the control room. This unit-pilot was chosen with respect to her/his competencies and experience. The second hypothesis is that the unit-pilot now compensate the phenomenon at two levels: s/he gives distantiated expertise regarding operations and s/he makes an additional brain available in the control room; this contributes to reinforcing the collective competencies and enables a compensating process. The following question is thus: until when will this compensating process work? Answering this question is the object of another study. However, we might conclude this short analysis by suggesting that the 3-pilot collective competencies might be adjusted to the new context and might positively replace the 2-pilot collective competencies which was suitable for the previous context (i.e. before skills drain). In the same way that the 2-pilot collective competencies had developed in and for the previous context integrating long-term experienced pilots, we might form the hypothesis that the new 3-pilot collective competencies will develop in and for the new context integrating short-term experienced pilots, hence coping with the aforementioned latent issues.

How many situation cases to observe to access what makes competencies of workers?
All workers participating in the study were experienced workers except one (Ref: ROS Coll Op AgT 01 - OpJ2). Three findings are worth mentioning and contribute to answer the question:

- Observing an experienced worker and analysing in details the activity with the SEBE/SPEAC protocol does not seem to need several situation cases.
  We compared analyses of similar activities during the applicative test segment (see Table 10). Similar activities are identified as hydraulic configurations, electric configurations or periodical tests in the table. Each similar activity gave the same results in terms of knowledge and know-how identified. Therefore, one activity appeared enough to analyse in the present study which addressed cooperative activities with systematized ways of doing, standardized procedures and stable means. Perhaps this could be different with co-constructive activities or less systematized ways of doing.
- Observing a novice worker supervised by an experienced worker may (not) bring additional relevant details when compared with the case of an experienced worker.
  The additional details obtained in this sort of case (reference ROS-COLL-OP-AGT 08 J3 in Table 10) concerned mainly the activity of pilot supervising a novice rather than the activity of pilot itself, i.e. hydraulic configuration; the additional details obtained were thus related to another activity than that observed.
- Observing the workers in SimS does not provide all data of the ROS.
  The comparison of hydraulic configuration activity observed in SimS (Ref: TEST-COLL-OP-AGT 01& 02 in Table 8) and ROS (Table 10) shows a difference in terms of the amount of knowledge and know-how identified (Table 20 and Table 21) as well as in terms of the nature of these. The ROS provide more data regarding the collective dimension of the activity and the SimS provide data devoted to the simulator even though it may be expressed the same way as for the ROS. For example, knowing how to use the procedure may be different in SimS and ROS if procedures are not presented with the same standard; knowing how to assess the correctness of a quantity may be different if the calculator for the monitoring of some parameters on a simulator is unable to reflect the real physical process with accuracy. The conclusion is that the SEBE/SPEAC protocol needs ROS.

Using other methods than the SEBE/SPEAC protocol to access knowledge and know-how
This point addresses the usefulness of the SEBE/SPEAC protocol to access knowledge and know-how. In other words, could another method lead to the same results? The answer is obviously "yes" provided that:

- a first-person perspective video is used for analysis,
- the interview is of the self-confrontation type,
- the SPEAC model is underpinning the structure of the interview or at least the analyst's questions for the interview; this means that the analyst must permanently bear in mind the four poles of the SPEAC model.

Regarding the video, the benefits of the first-person perspective video were identified, commented, argued and explained and that will not be done here again. Regarding the SPEAC model, as it was discussed above (§ "Subtleties of application of the SEBE/SPEAC protocol" in the present section), the main thing is to keep in mind the existence of the four interactional poles making successful competencies in action. Indeed this helps the analyst to ask the relevant and appropriate questions during the interview. This means that integrating the SPEAC model inside other protocols of the SEBE category or even, more widely, inside other methods of the "Process tracing" category identified in cognitive task analysis (Table 2) should contribute to improve the results; the assumption of improvement is based on the capacity to access data through a SPEAC model-based interview.

Complementing the SPEAC model
Another point of importance, which might be considered as a limit of the SEBE/SPEAC protocol, is that it might be restrictive if used without considering the interaction of the analysed activity with the other constituents of the socio-technical system in which it is carried out. "Restrictive" means that the analysis might be exclusively or excessively focused on the subject due to the subject-oriented nature of the protocol: questions are asked using "you" and the collected data is subjective. Despite the exogenous character of some of the poles of the SPEAC model, when answering the questions, the subject might focus on particular aspect of the pole. For example, *Being able to act* relates to means and to the help that other professions might provide; in case of problems occurring with tools whilst carrying out the activity, the subject might omit to talk about the needs of other professions.

A way of addressing this limitation is to guarantee a macro approach of the analysis by forcing the analyst to consider the subject as an interactional entity within an organizational system; the aim is to be sure to question and thus include interactions for example with other professions equipment and tools related to the subjects' activity. To do so, the set of indirect questions (see appendix 26) used to question the poles must be carefully elaborated.

This aspect was particularly emphasized during the analysis of the Test technicians' activity EP-RGL4 (ref: ROS-COLL-OP-TT-01). During the analysis of this activity captured in ROS, it appeared clearly that the measurement of the power curve was strongly dependent on the quality of the data collected from the DMA rack; this data collection was one of the first steps of the EP RGL4 activity. We were lucky that, during this early step, the Test technicians encountered a problem regarding the validity of the data and asked two other professions for help. If there had not been any problems, perhaps the replay interview would not have allowed highlighting the importance of the quality of the data and the necessity to know who to call for help in this case. This application in ROS being the first one of the applicative test segment, the subsequent improvement of the set of indirect questions was then applied to all other situation cases.

Among the possible tools likely to permit a macro approach of the activity, we selected the model of Engestrom (Engestrom, 2006; Engestrom et al., 2010 quoting Engestrom, 1987: p78) reproduced on Figure 7. The choice was oriented by the synthetic conception of the model combined to its detailed representation of the possible interactions between workers, workers actions and the sociotechnical system. Considering the possible interactions suggested by the model, the set of indirect questions for the SPEAC model was consequently enriched.

The SPEAC model, the resulting protocol, the results and conclusions of the tests and applications were published in Fauquet-Alekhine, 2016a and Fauquet -Alekhine et al., 2017a, 2017c, d, e.

Linguistic aspects of the replay interview

The language used by subjects to describe their work activity is not innocuous and may even be a source for understanding the activity beyond the literal meaning of the words or sentences. Psycholinguistic studies have been undertaken regarding discourse analysis and communication in the workplace (see for example: Limaye, 1992; Cameron & Webster, 2005; Roth, 2004; Andrén et al., 2010; Fauquet-Alekhine, 2009, 2010a, 2017a, 2017b) and have contributed to the demonstration that language through the discourse or the narrative may carry implicit depictions of the subjects' activities. Among these implicit elements of language, metaphors may offer new angles of comprehension of the subjects' activity (Lakoff & Johnson, 1980a, 1980b, 2003; Lakoff, 1993; Bogusławski, 1994; Glucksberg, 2003; Goddard, 2004; Steen, 2011; Veraksa, 2013).

Therefore, the detection and analysis of metaphorical language as a tool for work analysis during the replay interview is an aspect which should be studied in more depth. An example presented in section IV-1-1-d demonstrates its capacity to contribute towards the identification of tacit knowledge. The pilot's descriptions of block-watch around during the replay interview emphasized the way he was checking recorders; this was done using a metaphorical expression: the pilot said "je regarde si ça tire droit" (I watch whether it goes straight). This meant the pilot did not read the values of parameters on the recorders. He confirmed this point when asked and explained that for certain recorders or indicators, it was easy and fast to check a signal position rather than read the value according to the scale of the recorder and compare it with the expected value. This was done without losing any reliability on values. This gave rise to further analysis (Fauquet-Alekhine & Daviet, 2015; Fauquet-Alekhine & Green, 2017c).

Nevertheless, this aspect of the discourse has not yet been sufficiently explored regarding work activity analysis (see for example Wasonga & Murphy, 2006).

Psychological issues of the SEBE/SPEAC Protocol

Beyond the psychological and cognitive processes discussed all along the present study and focusing on the way the SEBE/SPEAC protocol may help analysts to access what makes competencies of workers, side effects were observed and are worth being mentioned here.

A positive aspect has already been presented regarding the benefits perceived by subjects for themselves just after the replay interviews (section IV-1-1-d, § "The applicative test segment for RCE criteria"). This will not be discussed again.

A potential negative aspect was also observed following one of the collective replay interviews between a pilot and a field worker (Ref: ROS COLL OP AGT O3 J1 & J2). This issue was linked with the intersubjective structure analysis during the collective replay interview. The pilot and the field worker had both independently completed an individual replay interview during which precise moments of the activity had been examined to assess the coherence of the intersubjective structure of collaboration. As for any replay interview, none of them knew how the colleague had assessed the perspective-taking: the collective interview which followed was precisely made to confront their respective standpoints, to obtain additional information regarding these standpoints and to enhance their perspective-taking, ex post facto. The collective interview was held during a nightshift in the Operations Dept. at 01.00am, in an office located one floor above the control room. The night shifts beginning at 09:45pm and ending at 06:15am, the interview took place sometime during the shift in accordance with the subjects' workload. During the collective interview, while the PhD researcher and the participants had viewed both excerpts of their subfilms regarding a specific moment for which

they expressed different perspective-taking (e.g. one considering they were collaborating, the other that they were not collaborating), the PhD researcher asked them what made this difference in their opinion. The activity context was a field worker's action on a valve while the pilot was expecting an immediate verbal feedback from him regarding this action by phone and meanwhile was checking parameters related to the activity on a computer in the control room. What is interesting here is not what they said but how they said it. It was clear that the field worker, who had expressed a positive intersubjective structure of collaboration (he had said he thought that he was working with his colleague and that his colleague thought he was working with him) was trying to excuse the pilot's difference in opinion (the pilot thought that was not a collaborative task) while the pilot's behaviour, facial expressions and speech depicted a kind of guilt. It was as though the fact that the pilot had a non-positive intersubjective structure of collaboration might mean that they were both at fault. Even the pilot, trying to argue his position (including long silences), then seemed to be ready to change his assessment. However, these details were not discussed during the interview, just discreetly noted by the researcher. The exchange regarding this particular point took a third of the interview time.
At the end of this collective interview, i.e. around 01:40am in this case, the pilot and the field worker went back to their work. Usually, the pilot goes back to the control room with the field worker, and after an exchange to agree and prepare the following activities, the field worker goes back to the field. This takes 10 minutes. However, on this night, half an hour after the end of the collective interview, the PhD researcher went to the control room in order to find a new participant for a next interview. Surprisingly, the field worker met in the previous interview was still there and, more surprising, the pilot and the field worker were still discussing their opposing standpoint regarding their irrespective intersubjective structure of collaboration. It was clear that the past exchange had created a kind of discomfort between the participants. It was also clear that the PhD researcher had to take time for an additional exchange in order to make sure the colleagues would still be able to work together after being sure they would understand the normality of opposed intersubjective structure of collaboration between co-workers. This unexpected exchange was not recorded but notes were then taken in order to have a trace of this event and, the following night, the PhD researcher tried to meet them again. Only the field worker was present as the pilot was having a day-off. The field worker accepted to come and exchange ideas about the previous night event in an individual interview which was held at 01:00am. The first question was about what the collective interview had been generating between them. The field worker explained that they wanted to understand better why the other was thinking in this way. The field worker said in his own words that he finally understood what the pilot was thinking but that he did not understand why he was thinking what he was thinking. Nevertheless, he reported that the pilot was considering "working together" as implying a compulsory communication link in real time unlike him. The next question concerned what they could conclude of this exchange: they found that whatever could be their viewpoint, this did not affect either the curriculum or the performance of the activity. Then the issue of a possible tension created between them due to this event was addressed; the field worker declared: "in my opinion 'no' since we made jokes [yesterday] after [our discussion]" (Ref: ROS Coll Op AgT 03\ROS Coll Op AgT 03 - AgT J2, t=03:00) and he added that he thought they would laugh about it when he [the pilot] came back to work. And what about the same situation with a pilot that the field worker would not like? The field worker explained at once that he would not have gone in the control room the previous night to discuss such a topic with someone he does not like and added: "we are not forced to like people with whom we work anyway". This short individual interview ended on the conclusion that there was no problem between the field worker and the pilot.

This storytelling points out the possible tension that the collective replay interview might generate between co-workers when confronting their direct and meta perspective of the collaboration. It also raises the subsequent potential issue that might occurred when co-workers do not appreciate each other: following the confrontation of their direct and meta perspective of the collaboration, if a non-coherence of intersubjective structure is found, this may create the starting point of a tension that might never be defused if the co-workers never discuss it. Perhaps no real conflict will emerge directly from this situation, but it may be one additional factor contributing to feed a future conflict.

The conclusion of the episode is that the analysts must be aware of this potential problem so as to be sensitive to details that would elude them and to manage the situation as necessary if applicable.

Biases and limits of the SEBE/SPEAC Protocol

Rieken et al. (2015: 256) pointed out that "Just as the presence of a researcher can affect respondents' actions (Wickström and Bendix 2000), so might the presence of the recording device change the behaviour of recording and recorded individuals." This was actually pointed out during the research at two levels:

- the third-person video recording: this approach was abandoned because of the need the preserve the subjects' spontaneity to access tacit competencies. At first it was assumed that this would yield loss of relevant information to understand the activity, but the course of the experiments showed that the first-perspective video combined with the subjects' comments was sufficient to reach a satisfactory level of information. The results obtained in terms of performance may be considered as a good indicator for it.
- the first-person video recording: subjects confessed that they were disturbed at the beginning of their activity and intended to show their best because of the recording device. However, they added that they very soon forgot about the subcam when involved in the nitty-gritty of the activity. In addition, should they have forced themselves to try to do their best, the bias would probably be negligible when related to the objective of the study: accessing what makes competencies of workers; the best way to obtain exhaustive results is to observe an experienced worker doing their best. Therefore, the bias induced by the first-perspective video is difficult to assess as it combines positive and negative contributions.

The tests and applications have shown that the SEBE/SPEAC protocol was relevant to provide input data for training program in terms of quantity and type of competencies identify. The actual efficiency can only be assessed when considering the effect produce when applied in simulation training. This is the aim of the following section IV-2. Then limitations of the protocol will be clearer.

IV-1-2-b The collaborative dimension of activities through the SEBE/SPEAC protocol

The analysis of the reasons evoked during replay interviews by the subjects explaining their perception of collaboration (bearing in mind that collaboration was here of cooperative type) showed that criteria defining collaboration could be hierarchized (section IV-1-1-d p. 130). The resulting list from the most important to the least important (among those which obtained significant percentage of associated comments) meets the early work of Bratman (1992) and posterior studies and this may be considered as an attestation of consistency of the data obtained. The two first criteria and the two last ones need comments.

The first criterion "communication" perceived to assign a collaborative nature to the activity is not astonishing as exchanging whilst carrying out the same activity strongly supports a collaborative dimension. Yet, surprisingly, Table 24 providing the proportion of coherent intersubjective structure between co-workers per activity phase indicates a low value for "Realization with face-to-face communication in progress" while it might be expected here the highest value. As mentioned in the right column of the table, all situation cases were remote activities; the realization involved very few face-to-face moments (6.4%) and the value is biased by an effect size. Conversely, and as expected, "Realization with remote communication in progress" clearly presents a higher percentage than "without communication".

The second criterion "sharing the general mutual goal" in the resulting hierarchical perception is not surprising either: this confirmed one of the pillars of Activity Theory considering activity as goal-oriented. By assigning a great importance to this criterion, the subjects unknowingly contributed to validate the theory or, reversing the perspective, matching the theory attested of consistency of the data obtained.

The two last criteria "mutual responsiveness" and "commitment to mutual support" underline the strength of the interdependence between the co-workers and emphasize the importance of the "collective subject" that we shall discuss in a next paragraph.

The intersubjective structure of collaboration was elaborated considering that a coherence between the interactants was an indicator of an efficient mental sharing between workers prior to carrying out the activity. This is not equivalent to an indicator of efficient or even of actual collaboration between workers. We prefer suggesting a more subtle comprehension by considering four cases, two reflecting collaboration and two others reflecting non-collaboration:

- There is coherence for the intersubjective structure of collaboration and co-workers perceive moments of collaboration as well as of non-collaboration:
  The assumption is that workers are involved in collaboration.
- There is coherence for the intersubjective structure of collaboration and co-workers only perceive moments of collaboration:
  The assumption is that workers are involved in collaboration.
- There is coherence for the intersubjective structure of collaboration and co-workers only perceive moments of non-collaboration:
  The assumption is that workers are not involved in collaboration.
- There is no coherence for the intersubjective structure of collaboration:
  The assumption is that workers are not involved in collaboration.

Furthermore, the concept of intersubjective structure of collaboration comes to invalidate the hypothesis formed by the management (section I-3): if workers are engaged in an activity supposed to be collaborative without perceiving themselves collaborating, then their performance is reduced as they quite probably do not use all the potentiality offered by the collaboration. Our results show that this hypothesis must be rejected: when there is coherence for the intersubjective structure of collaboration and co-workers perceive moments of collaboration as well as of non-collaboration, the assumption is that workers are involved in collaboration; these conclusions meet results of previous researchers as exposed in section II-4-3-a (Bardram, 1998; Bødker & Mogensen, 1993). Objections might be that the conclusions have to be balanced by comparing the proportion of coherent moments perceived as collaborative versus the proportion of coherent moments perceived as non-collaborative. A manifest hypothesis should be that a higher proportion of coherent moments perceived as non-collaborative should lead to the identification of workers that do not perceive themselves involved in collaboration. Our experiments were not designed to address such questions. Our results only indicate a significant relationship between job performance and coherent perspective-taking that may be extended to a hypothesis between job performance and effectiveness of collaboration. Indeed, the multiple linear regression model showed that job performance was mainly explained by the proportion of coherent perspective-taking (bringing quantitative results to support Gillespie & Richardson's conclusions (Gillespie & Richardson, 2011) that cooperative activity gains in performance when perspective-taking is applied as opposed to cases it is not) and the calculation of Spearman and Kendall's rank correlation coefficient showed that job performance scores and proportion of coherent perspective-taking statistically increased or decreased together (end of section IV-1-1-d). Hence, provided that job performance scores should be considered as a suitable indicator for the quality or the efficiency of collaboration and that the proportion of coherent perspective-taking should be a suitable indicator for the effectiveness of collaboration, the results suggest that the more the intersubjective structure of collaboration is coherent and the more efficient is the collaboration.

A coherent intersubjective structure of collaboration referring to the way subjects were able to accurately guess how co-workers might perceive their collaboration, this refers to the concept of "collective subject", i.e. the group of individuals (Lahlou et al., 2004; see also section II-4-3-a). In the light of Lahlou's comments, we may assume that the mental representation correctness of the co-worker's contribution to collaboration is the indicator that the co-workers' individual representations match a given representation which is shared: the mutual representation. As an extension, a coherent intersubjective structure of collaboration is the factor of performance for collaboration. This matches what was postulated when choosing the intersubjective structure of collaboration as a relevant factor to assess the efficiency of co-workers' mental sharing.

The question then rises regarding the coherent intersubjective structure of collaboration as a resource for the collaborative activity especially in its cooperative form: for example in case of means becoming unstable due to an unforeseen problem making necessary tools unavailable and requiring remedial solutions, might the fact that the intersubjective structure of collaboration is coherent contribute to help co-workers to deal with the issue more efficiently than in the case of incoherence? Probably yes, however we do not have any evidence of it since this was not observed in the studied situation cases. We only observed unstable means due to a default of structure of activity probably contributing to a mistake; when the mistake occurred, the activity then switched from cooperative to co-constructive when the co-workers tried to solve the problem. Before carrying out the activity, no clues were observed favouring mental representation sharing (especially, no PjB and no co-preparation) and replay interviews did not provide any elements in this perspective. Results obtained in the applicative test segment (section IV-1-1-d) showed that co-preparation or PjB, structuring the activity and coherent perspective-taking could be considered as three interactional factors contributing to cooperative performance:

- co-preparation or PjB seemed to favour structuring the activity,
- co-preparation or PjB seemed to favour coherent perspective-taking,
- structuring the activity and coherent perspective-taking seemed to be mutually beneficial.

This interactional combination suggests that, without co-preparation or PjB prior to carrying out the activity, both structuring the activity and coherent perspective-taking might be affected. Therefore, should co-workers tackle an issue making the means unstable due to a deficiency in structuring the activity, it's quite unlikely they would find a resource in the coherence of the intersubjective structure of collaboration.

Another point is worth to be discussed regarding the impact of influence on the efficiency of collaboration. It was found here that the workload did not have any influence neither on the performance nor on any other factors considered to describe the collaborate activity. However, this finding has to be weighted: when beginning studies with the shift with teams, it was agreed with workers and managers that the subjects involved in the experiments would be experienced and volunteers; therefore the managers suggested collaborative activities according to these criteria; similarly, workers who accepted to participate agreed because they were not afraid to expose their (lack of) competencies to the researcher; the proposed and volunteer subjects were thus experienced (at ease with the job) and, it may be assumed, self-confident regarding their competencies; it follows that the workload might be a factor of influence regarding their performance, nevertheless at a lower level than for less experienced workers. This means that, despite the fact that the workload was not a factor of influence for job performance, when replacing experienced workers by novices, we might have found that this factor had a significant influence.

We may finally suggest a definition for **collaborative activity at work**: **an activity that involves several subjects related to each other by organizational relations and timelines, aiming at carrying out a given task together with mutual responsiveness, sharing the general mutual goal related to this task, within a system that provides the organizational relations, and takes the form of cooperation when coordinating their actions**. An efficient system also provides means. Coordination implies communication for successful collaboration.

IV-1-2-c Limitations of the developed method

Is the method specialized?

The method was here applied to occupational activities at a nuclear power plant, i.e. in a high risk industry where activities are mainly bases on technical acts in the field. The professions analysed were technical. What about the activities of an assistant or a manager? Our conviction is that applying the method in these sorts of professions should pose no problem: the SPEAC model was developed on the basis of 50 different professions (see section III-1-1-b) of which 40% were managerial and 20% tertiary (appendix 6). These professions contributed towards validating the four-pole pattern of the model. Similarly, the four-pole model must be able to provide relevant output matrixes for these professions. Testing the application is planned with further experiments (out of the PhD framework) in the banking sector.

The SEBE/SPEAC method and the delayed interview

Might the delay between the activity performance and the replay interview have any influence on the proportion of coherent perspective-taking? The coefficient calculated for $N_{situ/app/coll}$ situation cases showed a poor correlation between the delay (calculated by adding the delay for both pilot and field worker per case) and the proportion ($r=0.23$, $p>0.23$) and no particular tendency was identified: for example, the 100% proportion of coherent perspective-taking was associated to delays spread all over the range of values for the delay. Therefore, we may conclude that the delay between the activity performance and the replay interview is not a limitation for the method.

The collaborative dimension analysis and subjects' characteristics

The characterization of the collaborative dimension of the activities and the link with job performance was considered in the present study both from individual and collective standpoint but the subjects' psychological characteristics were not addressed. Recent studies undertaken within Professor Alexandrov's team (Apanovich et al., 2016a, b) and described in section II-4-3-a showed that performance in collaborative activity was sensitive to the holist or analytic character of subjects. During Alexandrov's experiments, pairs of subjects were presented with a simple decision-making task: pressing a button when detecting a single visual stimulus, both subjects having a button in front of them. The exploration of their event-related potentials (ERP) through fMRI showed that decision making for analytic subjects was easier in competitive mode while it was easier in cooperative mode for holistic subjects. These conclusions are consistent with the subjects' respective cognitive style. To make it short, "holistic subjects" refers to the subjects' cognitive style that consists in considering elements of the world (objects, people, phenomena…) in their context viewed as a complex structure of interactions to which subjects pay more attention than to the elements themselves; "analytic subjects" refers to the subjects' cognitive style that consists in considering elements isolated from the rest of the world (Apanovich et al., 2016a). These conclusions suggest that not having taking into account this cognitive aspect might limit the generalization of the result of the present study. They also open the perspective of an extended research project analysing the influence of the cognitive style on the occupational collaborative activity, its dimensions and its performance.

IV-2 Elaborating and applying competencies in high risk industries

This was to answer:

RQ2: How are 'mobilisable competencies' elaborated through training in high risk industries?

This has been done in four applicative field experiments the results of which are presented one after another.

IV-2-1 Results for field experiments Chinon NPP– EDF SA - Activity: measuring neutronic parameters through EP-RGL4

Context:

In 2014, for periodical test EP-RGL4, the Director of Operations had asked the Training Center to implement a new training session on the piloting simulator. The design of the training session was undertaken by the Training Center. In parallel, the SEBE/SPEAC method was applied to an EP-RGL4 ROS. Training sessions launched in 2015 by the Training Center were observed by the PhD researcher in order to identify possible points of adjustment when compared with the SEBE/SPEAC resulting matrix (in appendix 23). The first 4 sessions (second semester 2015) were observed by the PhD researcher.

Design:

Training sessions were designed at the Training Center applying the SAT+description-based method presented in section II-3-3. However, application of the SEBE/SPEAC protocol showed that more than three times as much knowledge and know-how was necessary when compared with the Training Center method: observations of the training sessions had to provide proposals of adjustments. Three to four Test technicians plus a pilot attended a session as this periodical test involves actions on the nuclear control-command for which only a pilot is qualified and accredited.

The structure of the training session is described in Table 30. The purpose of these actions was to create steps of power while Test technicians were monitoring associated physical parameters. Test technicians asked for a step, then the pilot implemented the step and Test technicians measured the parameters. A first part took place in classroom in order to give trainees recalls regarding the process and specific process regulations. A second part took place on a piloting simulator in order to train Test technicians on the measurement of the reactor power curve (the purpose of the periodical test) involving actions on the nuclear control-command. A third part was the debriefing of the simulator run and took place in the classroom.

Table 30: Structure of the first training session for periodical test EP RGL4.

Time	Content
2h30	Preparation – theoretical recalls
3h	Run onto simulator
2h	Session debriefing

Results:

The first 4 sessions were observed by the PhD researcher summoning 14 trainees from the Test department and $N_{SimS/RGL4}$=12 filled in the “RGL 4 research questionnaire” (see appendix 3). Other sessions were also planned. Overall, 6 sessions were undertaken in 2015 and 2016 for a total of 19 trainees representing 95% of the whole staff from the Test department.

At the outset, it must be noted that the work environments were quite different between SimS and ROS: when 2 Test technicians work among 4 to 10 people watching them in the control room in ROS (Operations and Test teams) and interact with a few of them, in SimS, 3 to 4 Test technicians interacted with each other or with 1 pilot or 1 trainer. Interactions were thus quite different in ROS and SimS.

Table 31 reports the trainees’ level of expectation regarding the items identified as important through the SEBE/SPEAC analysis (extracted from the matrix {fields of competencies vs Knowledge & Know-how} in appendix 23) and examined through the RGL4 research questionnaire. It also compares these items with:

- what was observed during the simulation training sessions (SimS),
- what was expected after the SEBE/SPEAC analysis of the ROS.

They are presented in the table according to two domains: technical aspects and pedagogical aspects. The trainees’ level of expectation is quantified by a score averaged over $N_{SimS/RGL4}$. Results are presented in the table from the highest mean score to the lowest. These scores were obtained by coding the Likert scale from –2 to +2, +2 denoting a strong agreement. The Cronbach coefficient was α=0.62 attesting a satisfactory consistency of the answers.

Table 31 emphasizes that items #26, #27, #36, #37, identified as important by the SEBE/SPEAC analysis (thus validated by the experienced Test technician), were perceived important by the trainees (with a score greater than 1). Nevertheless, they were not seen during the training session.

Table 31: Trainees' levels of expectation (RGL4 research questionnaire mean score) regarding the items identified as important through the SEBE/SPEAC analysis and associated observations in simulation training sessions (SimS).

domain	related question numbers	items	mean score (from –2 to +2 =maximum of agreement)	observations in SimS	SEBE/SPEAC expectation
Technical aspects	21 22 (23)	recall of the GRE and DMA regulations is necessary (reversed) before (after) the run on the simulator.	2 0.8 (0.6)	Done Done before	Done Done
	29	The MO in simulation is representative of the ROS.	1.5	Done	Done
	26 27	At least one scenario must reach the point 48% power or must make trainees undertaking the tests expected just before reaching this point.	1.4 1.0	Done (partially or sometimes)	Done Done
	36-37	The need and contribution of On/Off regulation specialists is needed.	both about 1	Not Done	Done
	30	The phase for measuring the high point of G3 curve must be played in the scenario.	0.66	Not Done	Done
	38	The different professions needed to fix problems must be presented.	0.41	Not Done	Done
	31	Complements regarding prescriptions must be provided.	0.33	Done	Done
	35	Data analysis phase must be integrated into training.	0	Not Done	Not Done
Pedagogical aspects	32	The session debriefing is useful (reversed).	1.4	Done	Done
	33-34	The 2-hour session debriefing is enough, not longer.	both about 1	Done	3 h
	24	Two scenarios are required	0.58	Not Done	Done
	25	A single scenario is enough.	–0.25	Done (i.e. enough)	Not enough

NB1: question #20 is not presented in the table as it addresses the trainees' background.
NB2: "reversed" designates statements that were reversed compared with the original question.
NB3: As exposed in section III-2, items related to pedagogical aspects did not stem from the SEBE/SPEAC method but were motivated by the fact that the training specifications accepted by the Training Center would lead to summon too many participants for a one-day session.

There was no significant correlation between any question and gender or age. Age and experienced were not correlated together: a 2-year experienced technician was within the 31-40 age range as well as a 17-year experienced technician.
According to answers given for question #20, all trainees already participated to the test EP RGL4 in ROS (only once for 16.6%): correlations combining question #20 are thus not relevant. Not all participants expected the same things. The significant and relevant correlations were:

- Experience of subjects and preliminary tests (#27): r=–0.71; only the two more experienced workers did not need this.
- Experience of subjects and regulation recalls (#21, #22, #23) r<0.16: all appreciated recalls.
- Experience of subjects and single scenario (#25): r=–0.67; the younger, the less a single scenario was perceived as satisfactory.
- Experience of subjects and others professions: r=0.65 for On/Off regulation specialists (score(#35)=0.91) otherwise r=–0.78 (score(#38)=0.41); the more experience, the more was perceived the importance to recall the need of On/Off regulation specialists during training but the trend was the opposite for the other professions.

Other points related to technical competencies identified by the SEBE/SPEAC analysis and not worked upon during the simulation session were:

- dealing with the DMA data before engaging the test,
- identifying an erroneous point on the G3 curve,
- identifying acceptable/erroneous voltage,
- being able to carry out a pre job briefing based on the MO structure,
- being aware of the importance to tick the MO step by step.

Also points related to non-technical competencies identified by the SEBE/SPEAC analysis were not worked in the simulation session:

- staying alert during 30 min.,

- being able to carry out a pre job briefing in front of 5 members of an operations team listening and asking questions.

As explained above, these points were not included in the RGL4 research questionnaire because their number had to be limited.

Additional observations were found important when compared with other studies addressing training session structure and management (Fauquet-Alekhine & Pehuet, 2016; Fauquet-Alekhine & Boucherand, 2016b):

- The preparation and debriefing of the sessions tended to be reduced from one session to another: reducing the preparation led the trainer to transfer items not seen during the preparation phase into the simulation phase at the expense of experiencing practical exercises planned through the simulated situation; reducing the debriefing led the trainer to be more expository and thus to leave less time for the trainees' reflexive analysis of their simulated activity while this must remain a main step of the debriefing (see section II-4-1).
- The trainer was permanently intrusive during the run onto simulator: doing so, he was providing answers to most of the trainees' problems or making the trainees deal with the problems according to his way of thinking, thus avoiding letting them build on their own thoughts.
- The session debriefing was mainly expository even during the sessions where a longer time was assigned for this phase: the trainer had a tendency to manage the debriefing as he did with reminders during the preparation, i.e. as if following a list of items to be discussed according to the training program specifications. On the contrary, during debriefing, a self-generation of elements of analysis and of solutions must be sought by the trainees (see section II-4-1).
- The session debriefing was not projective, thus inhibiting or at least reducing the trainees' capacity to think how to elaborate their competencies in ROS from the SimS.

These observations concerned almost all the sessions undertaken in 2015. At the end of 2015, an appointment was scheduled with the trainer in charge of the RGL4 training session to compare the technical and pedagogical needs identified by each side (Training Center and LSE) and the expected content of the training session. Table 32 lists the main arguments for each suggestion regarding each points of divergence which all addressed items to be integrated in the session: therefore the "SEPE/SPEAC approach" column argues why it might be applied and the "Training Center approach" column argues why it may be done or not. The points identified as not necessary by the trainees (see scores in Table 31) were not discussed.

The arguments reported in Table 32 show that, among the 10 points of divergence including 4 relating to technical competencies, the trainer agreed to work one: the trainees' awareness.

Regarding the additional observations addressing training session structure and management, when presented with the remarks during the meeting, the trainer said that the list of technical points to be exposed and worked was consistent and this forced him to adopt an expository approach. Concerning his intrusive behaviour during the simulated situation, the trainer just said that it was a pedagogical choice.

Table 32: Arguments for each point of divergence regarding the EP RGL4 training session

Points of divergence	SEBE/SPEAC approach	Training Center approach
(26-27) At least one scenario must reach the point 48% power or work the tests expected just before reaching this point	This point was identified by the experienced technician as a crucial point ending the test.	Not always possible due to the time necessary to play one scenario.
(36-37) The need and contribution of On/Off regulation specialists is needed	If On/Off regulation specialists are not in the place during the test, it may be compromised.	Checking their availability in the place is the responsibility of the Operations team.
(30) The phase for measuring the high point of G3 curve must be played in the scenario.	This starting point may affect the following operations.	Not easy on the simulator.
dealing with the DMA data before engaging the test	This pre-requisite point may affect the start of the test.	Impossible on simulator.
identifying an erroneous point on the G3 curve	This point may affect the quality or validity of the test.	Not easy on the simulator.
identifying acceptable/erroneous voltage	This point may affect the quality or validity of the test.	Considered as part of the basic fundamentals of the profession: not relevant here.
being able to carry out a pre job briefing based on the MO structure	This may help co-workers to elaborate an appropriate mental representation of the forthcoming actions for each of them.	The trainer prefers the trainee to carry out a pre job briefing with a blank page for him/her to re-summon knowledge and not only read.
being aware of the importance to tick the MO step by step	This guaranties the compliance to the chronology of actions.	This must be seen in mentoring : not to be emphasized here.
staying aware during 30 min.	May be difficult when waiting without or too many any interactions with someone else.	This might be tested on simulator.
being able to carry out a pre job briefing in front of 5 members of an operations team watching and questioning	This point may affect the Test technician capacity to carry out the test: a non-experienced technician may be intimidated.	This must be seen during mentoring: not relevant here.

At the end of the meeting, the PhD researcher's following analysis led to three assumptions:

- the training session was not (and would not be) adapted to the operational need due to several gaps highlighted above,
- the trainer's refusal to integrate the SEBE/SPEAC suggestions might be a way not to rethink the session, in terms of content and method, and thus a way to avoid additional work for the trainer already overwhelmed,
- arguing a consistent list of technical points to be exposed and worked might be a pretext to be expository during the debriefing and have a good reason not to manage a 7S2P debriefing type described in section II-4-1; this was supported by other observations in the Training Center showing that a large part of the trainers were not updated with training session debriefing techniques (Fauquet-Alekhine, 2014b). The trainer's intent to avoid managing a 7S2P debriefing could be due to his perception of a lack of competencies for the debriefing techniques; this point could also come to justify his "pedagogical choice" of being intrusive during the simulator run: doing so, the simulator run was focused on technical points easier to debrief.

The conclusion of this exchange was that nothing would change.

Following the meeting, the PhD researcher contacted the managers of the Test teams in order to expose his conclusions regarding the current training session. A meeting was planned in April 2016; the delay was due to the managers' workload and to the fact that one of them was about to be replaced. The managers listened to the analysis but argued that, when speaking with the members of their teams, technicians were quite satisfied with the current session. The conclusion of the meeting was that some elements might have to be modified but later, in the perspective of future refreshing training.

The training session was subject to no change in 2016. However, at the end of the year, the performance improvement in ROS was not in place and thus not as expected by the management. The PhD researcher was contacted for a meeting with the Test department deputy manager in charge of training and a role-model technician. The meeting was planned on the 29th of December 2016. Results and conclusions obtained with the SEBE/SPEAC method were presented. The conclusion of the meeting was that new training sessions based on the SEBE/SPEAC results would be considered in 2017 in order to exceed the technical aspects of the activity during simulation training. At the same time, at the Training Center, a collective of trainers asked for a special training session for themselves addressing the methods to conduct the debriefing of a training session. This was planned in 2017 and taken in charge by the national department for training trainers of the company.

IV-2-2 Results for field experiments Chinon NPP– EDF SA - Activity: Application of Reliability Practices

Context:

Based on the analysis of the Operations Departments and on the second level analysis of support departments, the Operation management wanted to create a training session for Reliability Practices (RP) closer to the field of the operation professions for the operation teams. The objective was to enhance the skill level of the operation shift teams and consecutively to improve the level of quality and safety of work activities.

Design:

Mid 2014, the management of the Operations department established a working group (1 manager with a few operators and field workers) to develop a first version of a one-half-day session. Support was asked for from the PhD researcher since in charge of the study of professionalization strategy.

The management had decided to design an "in situ simulation" session: two groups of workers in the same shift team would go into the field separately mimicking their gestures to carry out different simulated activities. Procedures, moving and professional behaviour would remain however real. These activities would be the pretext to apply RP.

The PhD researcher suggested:

- reducing the pedagogical goals focusing exclusively on RP,
- elaborating scenarios for short and simple activities as they were just the support for RP,
- using the outcome matrix of SimS-IND-RefRP-01 resulting from the SEBE/SPEAC protocol application for RP in order to design the scenarios and conduct the following debriefing,
- implementing the SEBE technique on workers whilst carrying out the activities in the field (subcam: miniature camera mounted on glasses to produce a video in the first person of the work activity as support for debriefing); this was a result of the SimS-IND-RefRP-01 resulting from the SEBE/SPEAC protocol application which showed the importance of psycho-motor coordination,
- implement an innovative technique for a collective session debriefing (7S2P debriefing: see section II-4-1 and Fauquet-Alekhine & Boucherand, 2016b),

The final version was obtained after two experimental sessions at the end of 2014.

Structure of the training session:

The training session was a half-day session due to the shift teams heavy schedule.

Trainees attempted sessions in constituted teams, used to work together (no mixing from one team to another) mainly due to the operations schedule.

There was a ten-minute introduction giving the objective of the training session and its content. The voluntary field workers responsible for carrying out the work activity whilst wearing a subcam were chosen. After signing a consent form, they were equipped and SEBE risk assessment associated with wearing a subcam in an industrial context was conducted accordingly (see in appendix 7 the article presenting the risk assessment).

Two groups were formed, each managed by a pair of trainers (1 Human Factors Consultant + 1 operation manager). Each group prepared a simple activity (one on diesel and one on electric cells; see excerpts of subjective videos on Figure 45 a & b) and pre-job Briefing was undertaken with a manager of the team, an operator and a field worker. During this Pre job Briefing, according to the scenario, the manager required implementation of three RP: self-control, take a minute and if possible cross-checked by the fieldworker. Then, for each group, the field worker went into the field for the activity. He was accompanied by a field worker colleague who watched the procedure. The operators were available to answer all questions from the field worker by phone in two separate rooms. Scenarios provoked exchanges of points of view on fostering reliable communication. Especially, while the field worker was moving onto the workplace, the pilot had to call him by phone and ask a diverting task (controlling a parameter in a premise on the way) in order to check how this information would be taken into account, how the exchange would be made reliable and how the field worker would be disturbed or not.

After 20 minutes, the field workers returned to the classroom for a debriefing of the activity that had been carried out. All discussions, Pre job Briefing, Debriefing and telephone conversations were recorded. Doing so, all six RP were performed and recorded (audio or video).

a [redacted] [redacted] b

Figure 45 a & b : Excerpts of subjective videos of "in situ simulation" for the field experiment "Application of Reliability Practices", a)on diesel and b) on electric cells.
(ref : 20150914 seq 1 Int1 & Int2).

A break of 30 min. given to trainees was then necessary for trainers to analyse audio and video recordings to extract relevant sequences to work the debriefing of the simulated situation.

The 90 minute debriefing was collective (Figure 46), in particular to make the trainees think about what they had done in terms of reliability practices and what they had or had not succeeded in doing and for what reasons. Encouraged by the trainers, they also produced the solutions to improve their practices.

In optimum configuration, a second scenario was then carried out so that teams could implement areas for improvement that they had identified so that the trainees could leave the training session with the feeling of having been able to achieve practices in a satisfactory way (importance of leaving training with a feeling of success). In practice, this was not often possible.

At the end of the session, a questionnaire was filled in by trainees to express their views on the relevance, effectiveness and ease of implementation of the method (see appendix 8).

[redacted]

Figure 46: Example of collective debriefing for the field experiment "Application of Reliability Practices".
(ref : 20150914 Deb seq 1 Int1)

Results:

At the end of 2015, 14 out of 15 Operations shift teams had followed this training session[22].

Regarding the perception of the method applied during the sessions, the Cronbach alpha calculated for the aforementioned questionnaire was α=0.83 for the field workers (N_{FW}=63) and α=0.87 for the

[22] For information, the code of the training session is Y012.

pilots (N_P=28) showing a good consistency of the data. For the managers (N_M=22), α=0.52 increasing to 0.66 when suppressing the item regarding the constraining character of the method, showing a satisfactory consistency of the data.

Analysis of the questionnaire answered on a Likert scale coded from –2 (strongly disagree) to +2 (strongly agree) showed that, from the trainees' standpoint:

- analysing the subjective film was a real added value compared to training without subjective film (i.e. a method said "classic"): average score 1.36 with 91% ticked 1 or more,
- progress was faster regarding the studied RP by the proposed method than with a "classical" method: average score 1.1 with 90% ticked 1 or more,
- highlights particularities invisible with methods without sub-film: average score 1.18 with 92% ticked 1 or more,
- the overall perception was positive (not constraining for them, innovative, worth to be applied to other kinds of training sessions or other colleagues): average score 0.97 with 79% ticked 1 or more.

However, there were disparities for the item "constraining" and, overall, the field workers had lower scores than other positions as seen on Figure 47.

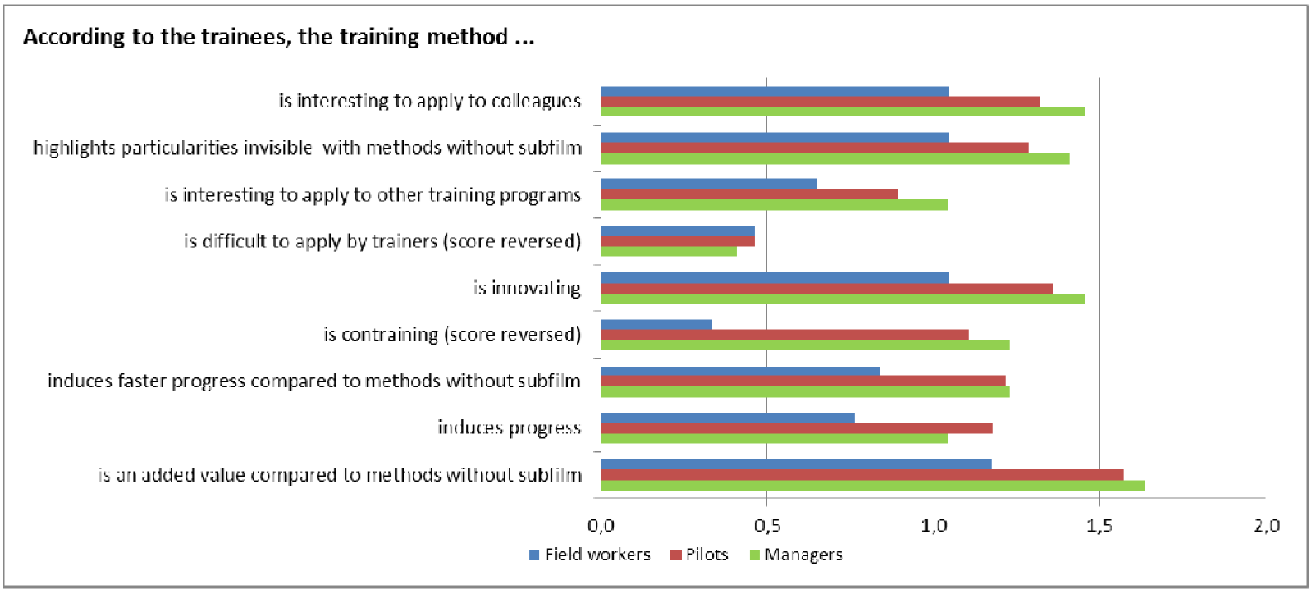


Figure 47: Average scores for each question evaluating the RP training sessions by trainees.

Regarding the subsequent gain of performance, the improvement was objectified through the annual safety analysis undertaken by all the analysts of the NPP (Fauquet-Alekhine et al., 2016e). The improvement was assessed on the basis of the indicator "safety events related to RP" calculated from mid-year to mid-year (this interval of one year is mandatory in order to include in each period the outage of each nuclear unit in each period and avoid a bias). These safety events are identified among all safety events: when the event is affected by the non-application of a RP or the incorrect application of a RP making the event potentially avoidable if applied as might be expected, the event is tagged "related to RP". Such safety events related to RP and under the responsibility of the Operations department:

- decreased by 30% over the last period, i.e. from mid 2015 to mid 2016, while they increased by 41.7% for all professions combined,
- the number of causes related to RP of these event decreased significantly compared with the overall result of the NPP (unilateral χ^2(1,df=2)=6.22; p<0.06),
- the Operations teams' contribution to this indicator significantly decreased over the last period regarding the proportion of events related to RP (-42% (z=2.26; p<0.023 for percentage comparison)) and significantly decreased regarding the proportions of causes of

event related to RP (-41% (z=2.80; *p*<0.005 for percentage comparison) as illustrated Figure 48.

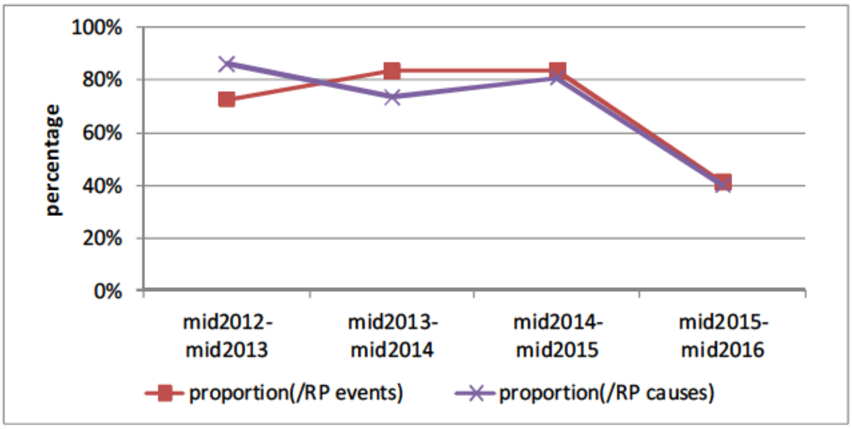


Figure 48: Operations teams' contribution to the performance indicator "safety events related to RP" compared to the overall "safety events related to RP" of the NPP (/RP event) and to the overall related causes (/RP causes).

However, these improvements were not only due to Y012 training sessions. In 2015, the management had also set up the DAL system (configuration activity file) supervised by the management which strengthened the implementation of this training program in ROS.
Following these results, a similar strategy was reinforced regarding the training sessions for Hydraulic configuration.

These results are published by Fauquet-Alekhine, Roudevitch & Lahlou (2017a). The head management of Chinon NPP now plans to generalize the use of the SEBE/SPEAC method in all operational departments and a project is being prepared for presentation to the company at the national level in order to diffuse the method throughout the nuclear fleet.

IV-2-3 Results for field experiments Chinon NPP– EDF SA - Activity: hydraulic configuration

Context:

Hydraulic configuration being part of most Operations teams activities and these activities having a non-negligible effect on the number of safety events (see footnote in section II-1) which does not decrease over time as might be expected (no significant improvement despite the application of several action plans), hydraulic configuration training was identified by the Operations department management as a possible area for improvement. This finding was especially supported by the fact that the trainees' feedback was really negative, contrasting with the positive Training Centre feedback. Therefore, the Operations department management asked for the application of the SEBE/SPEAC method in order to rethink the "hydraulic configuration" training sessions. On the basis of the results obtained during the applicative test segment in ROS, the 2015 CLIG session was re-designed.
The training sessions mainly address field workers and operator-pilots and to a lesser extent the managers: field workers are involved in the full scale simulator activities, operator-pilots are involved in the oral exchanges at each phase of the simulated activity (chronologically: preparation, realization, operational feedback) while managers do a pre job briefing which takes place between preparation and realization, and sometimes finish with operational feedback.

Design of the 2015 training session:

The training session was designed in 2011 for 8 participants over one day: 2 managers, 2 pilots and 4 field workers. They were divided in two groups: 1 manager, 1 pilot and 2 field workers.
During the morning, group 1 was preparing an activity and then carried it out on the field simulator. During this time, group 2 was attending a lecture in the classroom about the prescriptions and operational feedback regarding hydraulic configurations. In the afternoon, the groups swapped over. At the end of the day, a collective debriefing session was undertaken. Activities chosen for the scenario on the field simulator were:

- hydraulic configuration for operating a filter,
- hydraulic configuration around a valve after maintenance.

Table 33 gives the timelines for the 2015 CLIG training sessions.

Table 33: Timelines for the 2015 CLIG training sessions.

time	Group 1	Group 2
08h30 10h00	Activity preparation Simulator run	Referential & Operational feedback (classroom)
break		
10h30 12h00	Referential & Operational feedback (part 1 - classroom)	Activity preparation
lunch		
13h30 14h30	Referential & Operational feedback (part 2 - classroom)	Simulator run
break		
15h30 16h45	Collective debriefing of the simulator run (classroom)	
16h45 17h00	Synthesis of the session	

The trainers gave the same importance to applying Reliability Practices (RP) and hydraulic configuration operations.

The pedagogical approach was oriented towards the technical gesture and operational actions regarding both RP and the hydraulic configuration work.

During the runs on simulator, trainers made frequent corrections on non-compliant RP as well as hydraulic configuration work. This information was provided by trainee feedback. Regarding RP, traps were set by the trainers in order to check and assess the trainees' ability to implement RP efficiently but trainees felt "infantilized" and as if they were "being treated like idiot" (in French: "on nous infantilise", "on nous prend pour des cons").

The SEBE/SPEAC protocol applied for the structure & content of the 2016 CLIG training session

Key findings from the SPEAC analysis were used to help us to elaborate the new structure and new content of the 2016 CLIG sessions. A general finding was that an effort had to be done regarding the way Operations teams were working rather than on the individual technical competencies. At an individual level, what defined or not the effectiveness of a field worker was their ability to structure the activities and the sequence of reasoning and gestures rather than their technical skills (see section IV-1-1-d). Some field workers undertook final control of the activity or of a phase activity before moving onto another phase which guaranteed the non-compliance with expectations being detected. The field workers who applied the overall control always structured their activity. On the collective level, the collaboration was effective when it took the form of cooperation, which implied coordination by calibration prior to the activity and especially a preliminary work to share the same mental representation of the up-coming activity and the respective contributions. All this was related to transverse professional practices[23], that means not devoted to hydraulic configuration activity but applicable to other tasks. The SPEAC analysis showed that the time suited to this precondition was the pre job briefing.

Another source of improvement came from the assessment of the 2015 CLIG sessions through the two questionnaires presented in section III-2-2 § "*Chinon NPP– EDF SA - Hydraulic configuration*". Results are presented in appendix 28 §II. The trainees' answers permitted us to make a particular effort on the following aspects:

- simulated situations that did not make sense for the field workers (because too far from daily jobs) were avoided,
- operational documentation was reconsidered in order to reduce and even avoid unsuited documentation.

[23] These transverses practices might be considered as different from Non-Technical Skills (NOTECHS) as they are not related to any categories defined for NOTECHS. The NOTECHS framework consists of four main categories: Co-operation, Leadership and Managerial Skills, Situation Awareness, Decision Making (see for example Flin et al., 2003; McCulloch et al., 2009; Labrucherie, 2016).

- special attention was given to find activities or elaborate a simulation training context that would reduce the disconnection between the SimS and the ROS perceived by the trainees both on the figurative and operative dimensions.

The scenario was designed in order to adapt the simulated situation to a "hydraulic configuration" reference situation consisting in putting in/ removing equipment". This choice dealt de facto with the problem of documentation: within the chosen configuration, the production of a document similar to that used in the daily activities by Operations teams was easier.
To reduce the trainees' perceived disconnection from the figurative dimension between the SimS and the ROS, the opportunity was taken to improve transverse professional practices and therefore we adopted an approach of decontextualized SimS. Decontextualized simulation designates a training simulated situation where the context is quite different from the usual professional context of trainees (for example: being trained on a serious game relating to military management in the battle field in order to improve the leadership of managers in pharmaceutical laboratories). Indeed, it was shown that training transverses professional practices in decontextualized SimS could significantly increase performance for experienced workers (20%) compared to the contextualized training (10%) under specific conditions detailed in appendix 28 §I (see also Fauquet-Alekhine & Boucherand, 2016a). The assumptions were thus that working in a decontextualized situation would improve performance and would help trainees to perceive the contextualized SimS on full scale simulator less disconnected from their daily environment (contrast effect; see Plous, 1993).

To ensure the efficient reflexive analysis of SimS by trainees, it was chosen to implement the 7S2P debriefing after each simulated situation (Fauquet-Alekhine & Boucherand, 2016b). Description is given in section II-4-1.

The new 2016 CLIG training session was structured for the same number of trainees than as for the 2015 session with the same sample subjects' profiles.

The content of the new 2016 CLIG training session was elaborated as follows:

- trainees were briefly presented with the structure of the one-day session and were reminded that the aim of the session would be hydraulic configuration and not RP, even though RP would have to be applied when necessary,
- trainees were separated in two groups working in parallel on similar simulated activities presented hereinafter, first decontextualized in particular workshops and then contextualized on the field simulator,
- before each simulated situation, trainees were not told what would be the pedagogical goals and after the simulated situation, at the beginning of the simulator run debriefing, trainees had to guess what these goals were.

Decontextualization and contextualization had different pedagogical goals:

- decontextualized simulation would help trainees to improve in the structuring of their activity, traceability, overall final control,
- contextualized simulation would help trainees to improve what was seen in decontextualized situations and what makes the performance of collaborative work: coordination calibration during the pre-job briefing as well as sharing mental representation of the forthcoming activity, perspective-taking.

The structure of the new 2016 CLIG training session was elaborated as follows
Table 34):

- pilots and managers on the one hand and field workers on the other hand worked in pairs during decontextualized situations,
- decontextualized situations took place early in the morning, lasting 20 minutes followed by a one-hour debriefing,
- two 20-minutes contextualized situations were carried out at the same time in the second part of the morning,
- the consecutive one-hour simulation debriefing took place in the beginning of afternoon,

- two new 20-minutes contextualized situations were performed at the same time in mid-afternoon,
- the consecutive one-hour simulation debriefing took place at the end of the afternoon,
- assessment and synthesis of the session closed the session.

Table 34: Timelines for the 2016 CLIG training sessions.²

time	Groupe 1	Groupe 2
08h30 09h00	decontextualized simulation 2 workshops #F	decontextualized simulation 2 workshops #M
09h00 10h00	decontextualized simulation debriefing (classroom)	
break		
10h30 12h00	Activity preparation Simulator run workshop #1	Activity preparation Simulator run workshop #4
lunch		
13h30 14h30	contextualized simulation debriefing (classroom)	
14h30 15h00	Activity preparation Simulator run workshop #2	Activity preparation Simulator run workshop #3
break		
15h30 16h30	contextualized simulation debriefing (classroom)	
16h30 17h00	assessment and synthesis of the session	

All contributions regarding the technical points, the prescription and operational feedback were distilled during the simulation debriefing applying the generation effect principle as much as was possible.

Two decontextualized SimS were elaborated:

- Workshop #M - Mounting an insufflator (Figure 49):
  - Scenario: A cardiologist must mount a manual insufflator in emergency for the operating room in the absence of a specialist in the field. An insufflator is available but disassembled because just delivered by the sterilization lab. The cardiologist contacts an anaesthesiologist by telephone to assist him in mounting the device. The cardiologist has a checklist to verify that all the pieces are in the box and the anaesthesiologist has the same checklist plus a mounting procedure.
  - Means: manual insufflators, procedures, telephones.

a b c

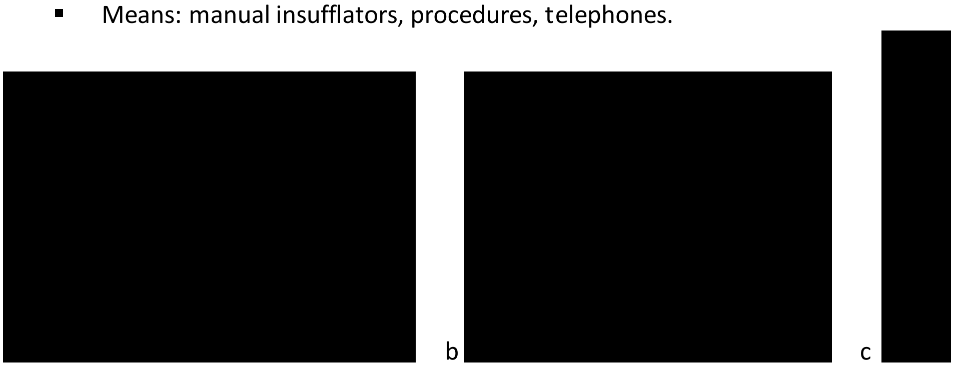


Figure 49: Workshop #M for medical decontextualized simulation: mounting a manual insufflator
a)the anaesthetist, b)the cardiologist, c)the mounted manual insufflator

- Workshop #F - Co-piloting a Robin DR 400 plane (Figure 50):
  - Scenario: Two future pilots have to take off a plane without completing their training because no experienced pilot is available. It is a matter of survival of a person to be rescued on the island off the coast. The control tower radioed them with a pilot instructor far from the aerodrome. The co-pilots have the check-lists and the instructor too: the latter guides the former on the manoeuvers to be done through the radio: one manoeuvers and the other checks the checklist. The simulated situation consists in taking off.

- Means: FightGear software (downloaded for free online) used on high tech computers connected with joysticks, procedures, telephones.

[redacted]

Figure 50: Workshop #F for flight decontextualized simulation: co-piloting a Robin DR 400 plane

Four hydraulic configuration scenarios were elaborated for the 200m² full-scale field simulator (Figure 51). All scenarios were technically identical to facilitate collective debriefing and comparison of the runs and in order not to favour one of the scenarios by the difficulties or the duration of intervention.

The structure of the activity of the scenarios was the same: back in (or remove of) operating a piece of equipment following or prior to maintenance work with risk of water leak during the operation. The task required handling 3 to 6 valves. None of the scenarios presented any trap or technical difficulty.

a [redacted] [redacted]

Figure 51 a&b: Contextualized simulated situation: hydraulic configuration scenario on full-scale field simulator.

Results*:*

Before presenting the quantitative results regarding the CLIG sessions assessment, an unexpected issue that was encountered during the negotiation phase needs to be addressed.

Issue regarding negotiation phase of the approach

As presented in section III-2-2 § "*Chinon NPP– EDF SA - Hydraulic configuration*", rethinking the CLIG training session consisted in several step among which:

- negotiating the availability of the field simulator and of trainers with the Training Centre in order to implement the new 2016 CLIG training session,
- negotiating participants for the new 2016 CLIG training session with the Operations Department.

The second point above might have caused deadlock as participation was voluntary. As the management of the Operations Department gave negative feedback of the 2015 CLIG session and as it was confirmed when discussing directly with workers, the number of potential attendants of the new 2016 CLIG session might have been low and destined the experiment to failure from the outset. In parallel to the management's email summoning potentials attendants, the PhD researcher sent each of them an email motivating them to come to the new sessions, explaining the new session format (incorporating innovative teaching devices, integrating the results of the observations made in shift teams, oriented towards the application in real operational situation), what might be the benefits for them (an effective improvement of daily activities) and what might be their contribution (help to adjust the content and structure of the session). Finally, this was not a deadlock point and the participation was very good, i.e. as needed.

Conversely, the first point above was not identified as a point of deadlock and yet this was. The CLIG training sessions were undertaken on the field simulator (already mentioned above for the experimental test segment). This simulator was under the responsibility of two field simulator trainers.

For each CLIG session, one of them was co-leading with a process trainer specially assigned to this task. As presented in section III-2-2, when rethinking the training session, at the first stage the process trainer was asked to collaborate with the PhD researcher as he had an Operations pilot's background and training; the field simulator trainers were planned to collaborate at the next stage as they had no pedagogical training but were responsible for managing the simulator including equipment control and maintenance as well as logistic and safety. It was judicious to work this way as the same had been done when developing the 2015 CLIG sessions: field simulator trainers had not participated towards their development. Yet, as soon as the new 2016 CLIG session project had been presented to management of the Training Centre, both field simulator trainers expressed a kind of opposition or resistance to the new format. Identifying whether it was related to opposition or resistance was crucial because this implied two different ways of dealing with the issue. As emphasized by Professor Bauer (1991, 2011a), resistance is not opposition: "Resistance to change is an informal way of expressing conflict. It is conflict awareness and behaviour which is not anticipated in form and content by the change agency. When institutionalized, resistance to change transforms into opposition" (Bauer, 1991: 184). In the present case, the field simulator trainers' expression being unexpected and sudden, it corresponded to resistance rather than opposition, but resistance to what and why?

Applying the taxonomy of resistance suggested by Professor Bauer (2011a: 16), it appeared that the probability that the resistance might be oriented towards the innovative nature of the project might be high. As exposed in section III-2-1, this innovative nature was unambiguous (Fagerberg, 2004; Maranville, 1992; Despa, 2013, 2014) and the innovation was "process innovation" as opposed to "product innovation" (see Bauer, 2011a: 20): the innovative nature relied on i)the fact that the content of the training session would address non-technical competencies rather than mainly technical skills as was done usually, ii) the introduction of decontextualization simulation was made despite the trainers having a long- standing culture of working on high fidelity full-scale simulators (see chapter I)

Two excerpts of Bauer's work depicted exactly what happened: "The innovator proposes a project that is not acceptable and rejected tel-quel by the resistor part; in that mismatch mutually unexpected expectations meet. Concrete actors may change their roles in two ways. First, the innovator resists changes to the project; and resistance may become an initiator" (Bauer, 2011b: 393); "it is unanticipated in the sense that members of the designer task force do not expect it in form and content" (Bauer, 2011c: 113).

In their recent External-Organizational-Individual model for resistance to innovation (the "EOI barrier model"), Hueske et al. (2015) identified 15 resistive dimensions to innovation regrouping 36 forms of expression of these dimensions among which one could address the present case: "Reservations regarding new and unfamiliar technologies (changes causes fears)" (p.56). Peccei et al. (2011) who addressed resistance as "a form of organizational dissent that individuals engage in when they find the change personally unpleasant or inconvenient" (p.188) mentioned potential behavioural consequences: low engagement in pro-change behaviours,
general failure to comply with explicit requirements for change, failure to cooperate with the change, speaking out against the change in public, or actively trying to undermine its implementation in the organization (p.188). Unfortunately, like many studies covering this field, these authors did not provide any pragmatic piece of advice to deal with such difficulties conversely to Professor Bauer's functional analysis of resistance; here, two main issues were to be considered: i) what was the fear of the resistors and ii) how could resistors become "initiators" (Bauer, 2011b). This last proposal met the generally accepted statement that "participative style carries benefits for the process of change" (Pardo del Val et al., 2012: 1843) .

The day after presenting the project to the Training Center management, the Training Center management urged the PhD researcher to meet the "resistors" as soon as it was possible since they had perceived a kind of growing discomfort among them. Due to holidays, week-ends and days off, the meeting happened two weeks later. The meeting took place in the resistors' office (both shared the same office in the Training Centre); the less virulent being on duty, the meeting was held with the person who was the more hostile towards the project (the other was met for the same purpose a few days later and the discussion was both calmer and shorter). The meeting was expected to last about half an hour but in fact went on for more than two hours. Briefly, first the resistor tried to make the demonstration that the current training sessions were of good quality and, without knowing anything of the new training structure and content, tried to argue that this could not work. Little by little, he was informed of the content of the session and he tried to prove that the associated workload could not be achieved from a one-day training session. He also argued that, even though it might work in the experimental phase with 2 trainers and 1 or 2 researchers managing 8 trainees divided into two simulated situations, the following nominal phase would not work with only 2 trainers. The resistor argued that it would not work, without the support of the researcher, and this several times during the exchange. Two hypotheses came to light: the fears fostering his resistance could relate to i) a potential increased workload for the trainer responsible for the simulator (himself) and ii)the possibility that the trainer might be asked to manage collective debriefing of simulated situations for which, one could assume he felt incompetent (in fact, at this stage of the exchange this was effectively what had been expected: field simulator trainers were supposed to conduct the collective debriefing session); in other words, this person would find himself in a difficult position. He was thus given details insuring that a Human Factors Consultant would support the 2 trainers during the forthcoming nominal phase and that debriefing would be the unique responsibility of the process trainer and consultant, not that of field simulator trainers. As soon as this was made clear, the resistor appeared open to discussing (and not just criticizing as he had done previously) the content of the project. Nevertheless, there was still an underlying desire to underline the trainees' ill will as a constant factor responsible for the difficulty in managing these sorts of training sessions correctly. This confirmed the aforementioned assumptions: the fears of resistance effectively related to the workload and to the possible incompetency in managing a collective debriefing session. Discussion becoming more open, the exchange slipped towards the possibility of observing trainees in simulated situations: scaffolding mounted over the control room of the simulator could be a temporary solution. We established a link between this issue and scaffolding that had been recently put up in one area of the simulator which apparently made the field simulator trainer particularly proud; he approved the idea and said that he had already suggested this kind of solution but it had been rejected by the management due to cost. He seemed pleased to have met someone who shared this view. He was asked about the different options which could be thought and at this moment, he had reached the status of "initiator". It was also the opportunity for him to express his competencies through a visible object thus increasing the importance of the scaffolding project.

At the same time as this change in attitude, another phenomenon appeared: the project changed. And it changed because of a necessary adaptation due to the resistor's fear. The change concerned the simulation session debriefing: before this exchange, it was planned that the field simulator trainers would manage the collective debriefing of the simulated situations. It was finally decided that a Human Factors Consultant would be present to support the 2 trainers in the forthcoming nominal phase and that the debriefing would be the exclusive responsibility of the process trainer and the consultant. In parallel to this immediate change, we may also consider that the idea of scaffolding for observing trainees was changing the project even though this would be a long term implementation.

As a conclusion to the resistance issue, working the two points based on Professor Bauer's work (fear and initiator) allowed us to avoid a contentious situation. On the contrary, cooperation became effective: field simulator trainers quickly did their best to provide efficient logistical support for the new sessions and worked to reshape the necessary documentation.

Quantitative results for performance

The comparative assessment of the CLIG sessions was possible only in terms of trainees' perception regarding their needs as explained in section III-2-2.

Assessments were based on two questionnaires, the CLIG Training Center questionnaire and the CLIG research questionnaire, both presented in section III-2-2 § "*Chinon NPP– EDF SA - Hydraulic configuration*". For the former, an average score tending to +1 (ranging from –1 to +1) would show a positive assessment; for the latter, an average score between +1 and +2 (range between –2 and +2) would mean a session had been assessed as being satisfactory.

A detailed report of the assessment is given in appendix 28 § II and III. Here follows a synthesis for an overview of the performance assessment.

Table 35 & Table 36 give the scores for each session and each questionnaire.

Table 35: Results for assessment of the CLIG sessions using the CLIG Training Center questionnaire.

Training Centre quest.	number of subjects	positive (%)	negative (%)	average score (2)
2015	83	90.6	3.0	0.86
2016	15	95.6	2.2	0.93

Table 36: Results for assessment of the CLIG sessions using the CLIG research questionnaire.

Research questionnaire	number of subjects	average score (1) (field workers)	average score (1) (pilots)	average score (1) (field workers & pilots)
2015	27	0.29	0.24	0.27
2016	15	1.28	0.93	0.96

It is clear that the scores calculated for the 2016 CLIG session are always higher than those for the 2015 CLIG sessions: the overall scores (right columns) show better trainee satisfaction with both questionnaires. To have a relevant comparison of their difference from one session to another, it is better to consider the difference over the whole scale of the score: from –1 to +1 for the CLIG Training Center questionnaire and from –2 to +2 for the CLIG research questionnaire. Doing so, the increase of 0.07 represents an augmentation of +3.5% regarding the CLIG Training Center questionnaire and an increase of 0.69 represents an augmentation of +17.2% regarding the CLIG research questionnaire.

Using a t-test of Student, the increase for the CLIG research questionnaire is quite significant ($t(df=40)=4.93$; $p<0.0005$) whereas it is not the case for the CLIG Training Centre questionnaire ($t(df=96)=0.49$; $p>0.6$).

Figure 52 presents a focus on the average scores per statement regarding (de)contextualization aspects for each profession (field worker and pilot) obtained when responding the CLIG research questionnaire.

All scores range between 1.13 and 1.67 illustrating a positive assessment of the usefulness of simulation and debriefing at a high level except from pilots for contextualized simulation with a score equals to 0.67; this is not surprising since pilots are involved in contextualized simulation only as actors on the phone in case of need while field workers are on simulator. A t-test applied on pairs of score per position (pilot vs field worker) or per type of the session (decontextualized vs contextualized) showed that scores do not significantly differ. However, statistically, this may be partly due to the low number of participants (one session was canceled reducing expected participants by a third).

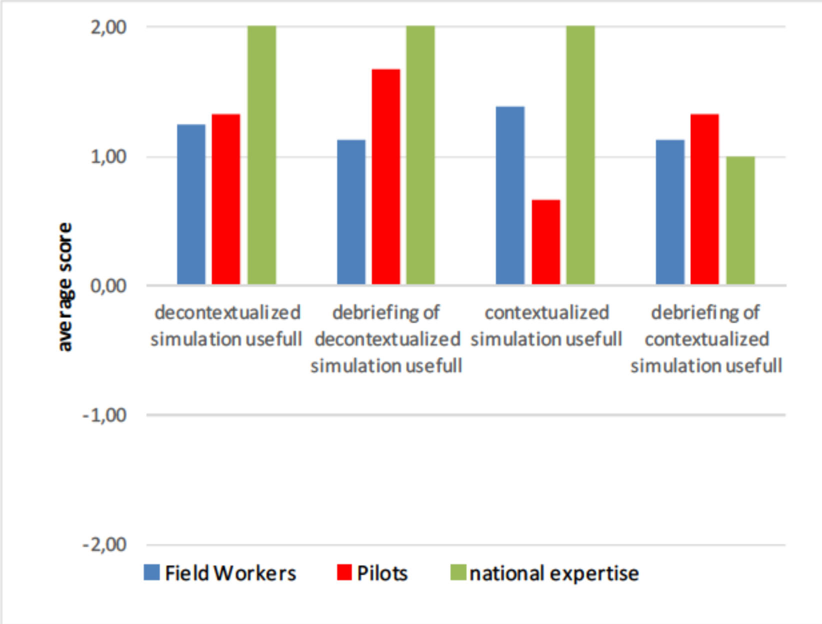


Figure 52: Average scores per statement regarding (de)contextualization aspects for each profession (field worker and pilot) obtained when responding the CLIG research questionnaire.
During the second 2016 CLIG session an assessment (in green) was given by a national expert (EDF SA-UNIE-PCCEO-Animateur métiers Conduite) who was invited to watch.

The CLIG research questionnaire also provided a qualitative assessment in terms of adjectives or expressions. Figure 53 shows a comparison of this perception.

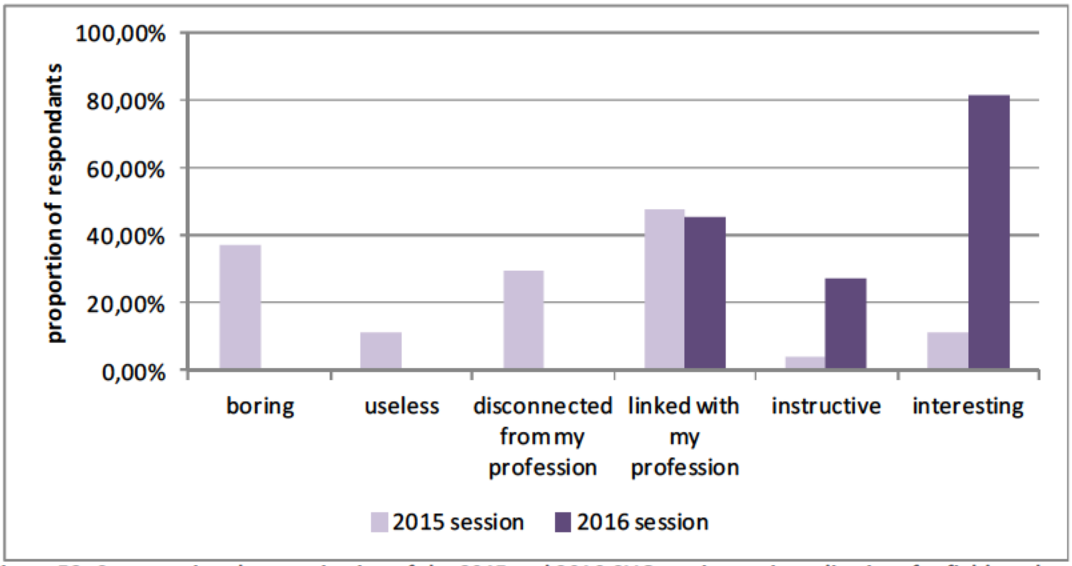


Figure 53: Comparative characterization of the 2015 and 2016 CLIG sessions using adjectives for field workers and pilots (grouped together) obtained when responding to the CLIG research questionnaire.

The 2016 CLIG session is clearly more positively assessed than the 2015 CLIG session except for the item "linked with my profession" which presents similar proportion for both sessions according to a comparative test of percentage (z=0.16; p>0.87: similarity is not rejected). None of the subjects judged the 2016 session with negative adjectives and a large proportion judged it interesting (up to 81%). The 2016 session was perceived as being in relation with the profession by half the trainees and none of them perceived it as disconnected from the profession. All this was a real progress compared with the 2015 session.

At the end of the sessions, a roundtable permitted the trainees to express their assessment and criticism. Overall, they found that the session respected the objectives announced, allowing the field workers to work their practices for each part of the "hydraulic configuration" activity, leading them to reflect on their own practices, with decontextualized SimS actually transposable onto the ROS and much better than the 2015 sessions. A few of them (especially one young manager) would have liked to have more training documents to read.

Following these experiments and the results obtained, a decision must now be made at both local (Chinon NPP) and national levels of the company whether to implement this new format of the CLIG session or not. Improvements in ROS performance should be expected in the year y+1. As the second 2016 CLIG session was given a quite positive assessment by a national expert (EDF SA-UNIE-PCCEO-Animateur métiers Conduite) who was invited to watch, (see appendix 28 §III), the decision might well be to deploy the new CLIG training session as well as the method more widely throughout the fleet.

These results are published in Fauquet-Alekhine, Daviet, Boucherand, Roudevitch & Lahlou (2017d) and Fauquet-Alekhine & Lahlou (2017e).

IV-2-4 Results for field experiments Un. Hospital of Angers, France - Activity: radial puncture

The SEBE/SPEAC protocol applied to a reference situation in ROS:

Analysis of the radial puncture in ROS was easy: a volunteer anaesthetist signed the informed consent form and scheduled a one- hour slot to record a film of the activity and another 2-hour slot for validation of the data. The hospital management dealt with agreements for video-recording.

A half-day meeting was then planned to analyse the results in the Training Center. The outcome matrix (see appendix 12) was used to identify what should be expected from the trainees; for each expected item, an observable was identified. Then the resulting table of 52 items was compared with the first version of the check-list (15 items) originally developed by the trainers. All of the 15 items were included among the 52 items. This work was carried out after performing the classic training session in order not to influence the way this session was usually achieved. The 52-item check-list was then reduced taking into account the fact that the session was for initial training, the specifications of the simulators and the duration of the session. The final check-list was 28 items (see appendix 11).

Structure and content of the training sessions:

The structure of both training sessions was similar and carried out on the same simulators (see Figure 54). The only adjustments made in the restructured session when compared with the classic session are underlined hereafter:

- introduction regarding the pedagogical goals and the structure of the session (10 min.),
- theoretical lecture and exchanges about ABG and related punctures (30 min.),
- individual simulation training (one student per simulator, 6 overall) with the help of the trainer and two role-model students and debriefing <u>following the rules defined by the 7S2P debriefing </u>(20 min.)
- sequence for assessment of students on simulator: students performed the task on simulator and the activity was filmed for further assessment on video (20 min.),
- debriefing of the session (10 min.).

Regarding the 7S2P debriefing, the description is given in section II-4-1 and in Fauquet-Alekhine & Boucherand (2016b). Little modification was necessary to transform the debriefing into the 7S2P form: the generation effect principle had to be reinforced, the projective perspective had to be applied especially to carry out a comparative analysis between what had been experienced during the run onto simulator and which should be lived in the future ROS.

The content of the restructured session included all of the first “classic” session with an enhanced contribution for certain points resulting from the SEBE/SPEAC analysis:

- The presentation of the operation to the patient WITH patient identification and oral informed consent.
- The appropriate time for hand friction with hydro alcoholic solution.
- Handling compresses (opening the package in the right way may help).
- Verification of the absence of bubbles.

- Compression of the artery is immediate and prolonged.

Subjects:

Table 37 gives characteristics of the medical students who attended the sessions.

The characteristics were slightly different from those presented in section III-2-2 “Material” as one of the restructured session subjects was rejected due to a lack of commitment: during the training session, all the trainers and researchers agreed that this subject’s behaviour illustrated a lack of rigour; in addition this subject’s motivation assessment gave one of the two lowest scores; finally the performance assessment was the lowest of the sample.

Table 37: Subjects’ characteristics for radial puncture training sessions of residents at the medical Training Center of Angers (France).

	Classic training session	Restructured training session	All
Gender (% male)	25	27	25
Age (y)	22.5	21.0	21.75
Experience (y)	4th year	4th year	4th year
Number of subjects	12	11	23

NB: Classic session is without applying the SPEAC protocol, estructured session is when applying the SPEAC protocol.

Figure 54: Trainee on simulator for radial puncture
Source: SimS-Med T01-010 (t=04:48)

Results:

The motivation scales being assessed on a seven point Likert scale from 1 to 7, we found that all subjects presented a score for each selected motivation scale higher than the average 3.5. Data are presented in Table 38. The Cronbach coefficient was α=0.69 for the first sample of subjects and 0.80 for the second denoting a good consistency of the answers. The MSLQ scores (individual and averaged per sample) showed an effective commitment of the subjects.

Table 38: Results of motivation self-assessment using MSLQ for medical training.

Session type ↓	**Motivation scale →**	**Extrinsic Goal Orientation**	**Task value**	**Self-Efficacy for Learning and Performance**
Classic session	Proportion of subjects over the average value 3.5 of the MSLQ	100%	100%	100%
	Mean score of all subjects on MSLQ	4.79	5.40	5.41
Restructured session	Proportion of subjects over the average value 3.5 of the MSLQ	100%	100%	100%
	Mean score of all subjects on MSLQ	4.75	5.00	5.56

No significant correlation was identified between performance and motivation scales except for one rejected subject. No significant influence on motivation was identified neither from gender nor from age.
Table 39 gives the comparative performance results for each session. The scores are averaged per sample. The maximum possible score was 68.

Table 39: Performance results for the "classic" and the restructured "radial puncture" sessions.

Session type	mean score	% of max score	% scores > 90% max score	SD	SD/mean score (%)
Classic session	55.50	81.62	16.67	6.05	10.90
Restructured session	63.09	92.78	88.89	2.75	4.35

Results showed a significant improvement in the performance of the restructured session when compared with the classic session:

- the average score of the sample increased by more than 13% (t(df=21)=3.98; $p<0.001$ for a t-test),
- the standard deviation was more than halved,
- the percentage of trainees whose score was over 90% of the maximum score was multiplied by more than 5.

No significant correlation was identified between performance and the fact that they already had carried out this operation in real operating situations. For the "classic session" sample, 50% of the subjects had already carried it out versus 33% for the "restructured session" sample.

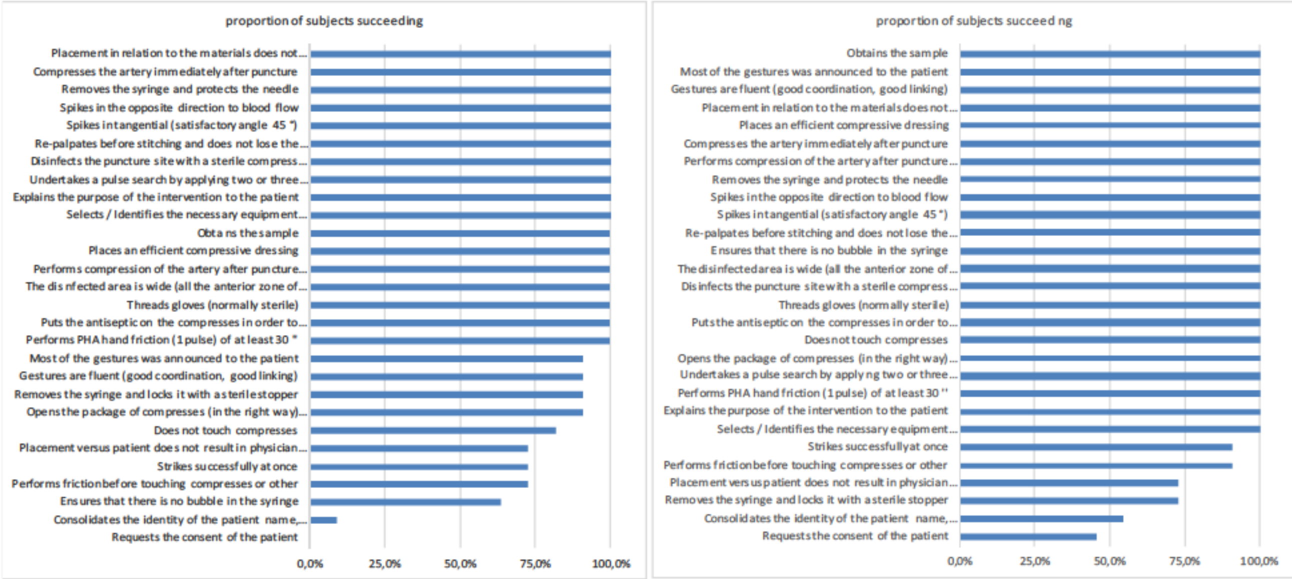
The main improvements regarding the professional practice concerned (Figure 55 a & b):

- asking for the patient's consent,
- asking for the patient's identity,
- managing the compresses correctly,
- managing the hand friction with hydro alcoholic solution correctly,
- ensuring that there is no bubble in the syringe,
- gestures are fluent (good coordination, good linking),
- striking successfully at once.

The remaining issues concerned:

- no asking for the patient's consent (50% of the subjects vs 100% in the previous session),
- no asking for the patient's identity (41% of the subjects vs 91% in the previous session),
- not locking the syringe with a sterile stopper (16% in both sessions)
- not placing an efficient compressive dressing (25% of the subjects vs 33% in the previous session).

What is important to note on Figure 55 is that i)all that was achieved with 100% success in the classic session (Figure 55 a) was kept at this level in the restructured session (Figure 55 b) and ii)the other items were increased from the classic to the restructured session.



a b

Figure 55 a & b: Proportions of subjects performing the actions successfully a)during the classic session and b)during the restructured session.

Regarding perceived stress, results were surprising.

Table 40 gives the comparative self-assessed stress using ALES questionnaire for each session. The scores are averaged per sample. The maximum possible score was 80. As done elsewhere, we separated adjectives regarding "constraints" and "excitement" (see appendix 10 and Fauquet-Alekhine et al., 2015b) and analysed their respective contribution to the overall score per sample.

Table 40: Results of self-assessed stress using ALES questionnaire for the "classic" and the restructured "radial puncture" sessions.

Session type	ALES constraint score: M ; SD	ALES excitement score: M ; SD	ALES score: M ; SD	Proportion of constraint (resp. excitement) to ALES score
Classic session	4.4 ; 6.8	15.0 ; 5.7	19.5 ; 9.95	22.6% (77.4%)
Restructured session	1.8 ; 2.2	17.6 ; 3.7	19.4 ; 4.64	9.3% (90.7%)

Results showed that the overall scores (ALES score) were similar for the two sessions (t(df=21)=0.013; *p*>0.999 for a t-test) but that the contribution "constraint" and "excitement" were different: excitement contributed towards more than 90% of the stress during the second session whereas it was less than 78% during the first session. In addition, the standard deviation was divided by more than 2 as it had been for performance.

These results were published by Fauquet-Alekhine et al. (2017d). The Medical Training Centre now plans to apply the results of the SEBE/SPEAC method to an enhanced simulated situation of radial puncture and to apply the SEBE/SPEAC method to more complex activities.

To summarize results of section IV-2: The outcome of the SEBE/SPEAC method was used in the design of training programs. Four field experiments were obtained for application, three in nuclear industry and one in medicine.

The first field experiment (at Chinon NPP) helped us to highlight areas for improvement regarding the training session designed by the Training Center for the activity "measuring neutronic parameters through EP RGL4". The second field experiment (at Chinon NPP) permitted to design a new training program for Operations teams applying Reliability Practices, leading to a high level of satisfaction of trainees and to high improvement of activities in terms of safety indicators (42% higher than for other teams). The third field experiment (at Chinon NPP) permitted to design an innovative training program to replace training sessions (CLIG sessions) for hydraulic configurations which were rejected by trainees, members of Operations teams: the restructured sessions based on the applicative test segment results increased trainees' satisfaction by 17.2%. This restructured session was also positively assessment by an EDF national expert. The last field experiment (at the Medical Training Center of the University Hospital of Angers) improved trainees' competencies for radial puncture from 81% to 92% and the percentage of trainees whose score was over 90% of the maximum score was multiplied by more than 5. It also significantly reduced the negative effect of stress during training.

IV-2-5 Discussion for the elaboration of competencies in high risk industries

IV-2-5-a Field experiments that fell through

Analysing the context of the field experiments that fell through give relevant clues contributing to understand why they fell through despite the clear interest of the participants and the potential benefits which were identified. Two cases were concerned: training of future pilots of the new European nuclear Pressurized water Reactor (EPR) in Hinkley point (EDF Energy, UK) and training for taking off or landing for novice pilots of the Air Force (Salon-de-Provence, France).

A main point is that, in both cases, the deadlock came from a contributor external to the direct participants. In both cases, the direct participants could be considered as being an organizational system made up of four entities: an operational entity (Operations departments for EDF Energy, flight fighters for the Air Force), an occupational training entity (the training center for EDF Energy and the army flying school for the Air Force), an intermediate entity supporting the project made up of two parts (the national Human Factors pole for EDF Energy and the research center for the Air Force in both cases engaged with the LSE through the PhD researcher). This configuration was similar to the organizational system regarding two of the completed field experiments for the French nuclear industry: in the case of Hydraulic Configuration improvement, the NPP Head Management department supporting the project and engaged with the LSE through the PhD researcher was an intermediate entity between the Operations Teams and the Training Center; in the case of periodical test EP-RGL4 improvement, it was the same between the Test departments and the Training Center.

The external entities were of different nature in each case. For the French Air Force, the external entity was the special Air Force bureau qualifying the equipment allowed on board planes. For EDF Energy, the external entity was the British government which announced the Brexit following the people's vote. However, at the scale of a company, in the case of the French Air Force, the entity external to the 4-part system was nevertheless part of the "company" whereas in the case of EDF Energy, the entity external to the 4-part system was outside the company. Nevertheless, the resulting reactions took similar forms: in both cases, one entity of the 4-part system decided not to be engaged in the project mainly because of a potential decision of the external entity.

IV-2-5-b Engaged & Completed field experiments

Field experiment: Chinon NPP-EDF SA / measuring neutronic parameters through EP-RGL4

For this field experiment, the adjustment of the training session using the SEBE/SPEAC results remained at the state of project conversely to all other field experiment. The 10 points of divergence between the SEBE/SPEAC approach and the Training Center approach presented in Table 32 might have given rise to adjustment of the session but it was not the case.

The fact that the Test technicians gave a positive feedback of the training session to their management was an essential factor for the Test department management not to ask the Training Center to advance adjustments. This positive feedback was interpreted by the management as a relevant and confident indicator that the training session in its current format was adapted to the need. This interpretation was not injudicious when postulating that no one is cleverer at defining what is needed than the user. However, in the field of education and occupational training, it does not work; if this were the case students at university would be asked to provide the educational program for themselves and this might lead to some kind of disaster. At the same time, the fact that the answers to the RGL4 research questionnaire showed that some points of competencies (technical as well as non-technical) were expected by the trainees while not worked in the training session does not mean that these points had to be integrated in this session: the hypothesis is that a course made up of two complementary sessions might be envisaged, the first one focusing on the technical minimum required to carry out the activity correctly and the second refining the enriching the technical aspect and integrating the non-technical aspect. This consideration illustrates how the exhaustive set of input data (such as that provided by the SEBE/SPEAC method) used to choose the pedagogical objectives and the associated content of scenario must be adapted when designing a program for simulation training. The adaptation must take into account the characteristics of the targeted activity (what are the overall competencies), the characteristics of the trainees (novices or experienced, engineers or others) and the characteristics of the simulator available as described by Samurçay & Rogalski (1998) (see Figure 13 section II-4-2). This aspect of the design will be fully discussed in the next section “Field experiment: Un. Hospital of Angers, France / radial puncture”.

However, what can be done during a training session also depends on the pedagogical methods applied and observations reported in section IV-2-1 make us form the hypothesis that the performance of the session might have been significantly improved.

A final comment must be made regarding the dynamic of the project. In section III-2-2 § “Periodical test EP RGL 4”, the description of the context and the associated dates show that it took 2.5 years from the starting point of the project to the date for the decision-makers beginning to think that the simulation training session might be adapted or complemented. The length of the period was mainly due to a 6-month delay to obtain the expected ROS, about the same for observing the training sessions developed by the Training Center and finally the time necessary for the management to make its own opinion regarding the efficiency of these sessions on the safety and production results, i.e. several months. This is a typical example of the inertia encountered in complex socio-technical systems. It also illustrates the systemic dimension of occupational training in complex sociotechnical systems: this is not just a question of trainees and trainers experiencing a simulated situation designed from a reference situation on a simulator. With these components (trainees, trainers, reference situation, SimS, ROS, simulator) must be taken into account the entities from which they depend and the resulting interactions (e.g. contractual relationships between the NPP and the Training Centre), that is the organizational dimension of the system.

Field experiment: Chinon NPP-EDF SA / Application of Reliability Practices (RP)

The field experiment “Application of Reliability Practices” was developed within an organizational system involving 2 entities interacting together: the LSE with the PhD researcher was in direct interaction with the Operations departments. In this configuration, the project was fast (training program completed in one year for 15 Operations teams) and efficient (effective improvement of safety and production performances). This configuration was characterized by a fast circuit for decision-making (decision-makers and trainers in the same department) and the absence of an external entity capable of interfering in the decision making process.

Also, at the same time, the training program was well accepted by the trainees: Figure 47 (section IV-2-2) exhibits scores illustrating an overall positive perception (answers to the multiple choice questionnaire in appendix 8 were coded on a Likert scale from –2 (strongly disagree) to +2 (strongly agree). This was not a priori obvious as the method applied exposed the trainees to colleagues and trainers, especially for the field workers wearing the subcam and having to put into discussion their professional practices in collective debriefing. This aspect was visible when comparing the field workers’ scores with those of other positions (pilots and managers): field workers’ scores showed a positive perception almost always lower and, unsurprisingly, the explicit question regarding constraint was also associated with a higher perception of constraint (lower reversed score) for field workers while they were the only ones directly experiencing directly the constraint.

Furthermore, the method was perceived as less constraining in ROS (the applicative test segment) than SimS (RP training sessions) by subjects on the whole. This may be explained by the fact that, during RP training sessions, subjects were involved in "in situ simulation" (activities must be simulated in the real operating field) and the reflexive analysis of the sub-film was undertaken in collective debriefing while during the applicative test segment the reflexive analysis of the subfilm was carried out between the subject and the analyst only, hence less exposing the subject as less "spectators".
Another factor may have influenced this perception too: a characteristic differing from one context to the other related to the orientation the context contribution. During the applicative test segment, subjects were asked to contribute to provide data for their professional community to improve training. The context orientation was towards the Other and it was assumed the Other would ask for it through the motive of the research project. During the RP training sessions, subjects were asked to contribute to provide data to improve their professional practices. The context orientation was towards the Self and the Self (i.e. themselves) did not ask for anything. The first context had a philanthropic nature whereas the second had a constraining nature. This remains at a hypothetical stage as the questionnaire did not give reasons for these perceptions, being a multiple choice questionnaire; analysing qualitative matter was not selected so as not to increase the quantity of data that would have to be processed; furthermore any added value would be difficult to estimate.

Regarding the results obtained and illustrating a significant improvement in ROS, it must be noticed that, although the contribution of the SEBE/SPEAC method was clearly demonstrated by providing relevant and exhaustive input data for the training program, the success of the training sessions resulted of an adjusted combination of several components among which especially, for this field experiment, the use of subcams during the simulated situations and the application of the 7S2P debriefing. The main contribution of the sub-cams during the simulated situations was to work as a learning accelerator permitting an accurate understanding of what was done and what had to be done for trainees. The main contributions of the 7S2P debriefing was the reflexive analysis and the projective perspective (see section II-4-1).

Field experiment: Chinon NPP-EDF SA / hydraulic configuration
Training sessions in their 2016 form gave rise to a positive assessment of an internal observer (the national expert) and to a positive perception of the trainees at a level significantly higher than this related to the 2015 training sessions. These assessments must nevertheless be considered with caution: a bias may have influenced the perception through the pleasure experienced by trainees compared to the previous session. First, giving pleasure to trainees is not equal to making them elaborate the expected competencies for the targeted professional activities. In other words, trainees may even feel pleasure while the training session does not relate to the targeted professional activities. We assume here that, despite the objective nature of the questionnaire and its accurate orientation towards specific pedagogical contributions for their profession, the pleasure experienced by the trainees might have positively influenced their assessment. In addition, the perception of the previous session being actually not positive, the pleasure to discover an interesting new format of session might have been artificially amplified (the relativity or "contrast effect", see Plous, 1993) amplifying at the same time the aforementioned bias. However, the assessment is sufficiently significantly different between the two sessions to assume that, if this bias affected the amplitude of difference, it did not affect the effectiveness of the difference. As for the field experiment "Application of RP", the best way to assess the efficiency of the training sessions is to assess the performance improvement in the subsequent ROS (with was not possible in the framework of the PhD).

Regarding the overall assessment of the sessions, another point must be discussed: the apparent contradictory difference between assessment results of the two surveys, the Training Center questionnaire and the researcher questionnaire.
When applied to the 2015 CLIG sessions, there was a potential bias due to the nature of the population of respondents, and to the context of the completion of the questionnaire.

Regarding the nature of respondents, those responding to the Training Center questionnaire included managers less concerned with hydraulic configuration than the pilots and field workers. In contrast, respondents to the researcher questionnaire included only pilots and field workers.
The context of responses to the Training Center questionnaire was the end of the session on a day: some trainees confessed to completing the questionnaire quickly ("which serves no purpose" in the opinion of some of them) in order to leave as soon as possible. The researcher questionnaire was completed when respondents had time to devote to it; if not, they did not respond. This is why the results obtained with the researcher questionnaire might have been slightly more incisive, thus increasing the amplitude of the difference.

Another factor contributing to the difference between the surveys from one questionnaire to another comes from the nature of the questions. The Training Centre questionnaire is a kind of overall assessment, with four questions addressing the training session form (questions 3-6), four questions addressing the training session substance (questions 1, 2, 8, 9) and one addressing the means (question 7). Regarding the research questionnaire, all statements are focused on the substance except #5 which is of general nature. According to us, this mainly explains why the Training Center questionnaire is less differentiating. This comparison raises the hypothesis that the synthesis questionnaire used by the UFPI might be inadequate when assessing the appropriateness of the training session to the profession.

Regarding the assessment of the 2015 CLIG sessions using the research questionnaire, one point might appear contradictory: although the sessions were perceived as being in relation with the profession by half the trainees (around 50%), it was however perceived as disconnected from the profession by 25% (Figure 53). This may be explained as follows: the 2015 CLIG training sessions were actually in connection with the profession through its themes because it dealt with hydraulic configuration; at the same time, it could be perceived as disconnected from the profession by its content. Regarding the 2016 CLIG sessions, one might have expected a higher score for the item "instructive" which increased from 4% in 2015 to 27%. The synthesis discussion engaged with the trainees at the end of the 2016 sessions showed that this low score might be due to the fact that training is focused on non-technical competencies while "technicians" usually expect any training to address the fundamentals of their profession, that is technical skills. The very low score for the 2015 sessions thus suggests that the "skill-focus" was not well targeted.

Regarding the results obtained and illustrating a significant improvement of the trainees' perception, it must be noted that, although the contribution of the SEBE/SPEAC method was clearly demonstrated by providing relevant and exhaustive input data for the training program, the success of the training sessions resulted of an adjusted combination of several components among which especially, for this field experiment, the application of decontextualization during the simulated situations and the application of the 7S2P debriefing. The main contribution of the decontextualization during the simulated situations was to make trainees rediscover their transverse professional practices permitting a new understanding of what was done and what had to be done for trainees. The main contributions of the 7S2P debriefing was the reflexive analysis and the projective perspective (see section II-4-1).

It is worth reminding a limitation in the 2016 CLIG session here: it is due to decontextualization and this was already highlighted in the original work promoting this type of training (Fauquet-Alekhine & Boucherand, 2016a). It was pointed out that decontextualization was efficient provided that the trainees could summon past experience for the simulated activity, meaning that the new format of the CLIG session is not adapted to novices. Similarly, Lendvay et al. (2013) showed that training on virtual application as warming up before the real operating situation could give significant benefits for experienced workers but not for novice workers. However, this aspect is more a characteristic of the session than a limitation as the trainees' profile for the CLIG session is that of qualified workers, therefore not novices.

Management of resistance to innovation:
In the storytelling depicting the exchange between the PhD researcher and the resistor (field simulator trainer), it was noted that the project changed whilst dealing with the resistance. This happened when tackling the resistor's fear. Hereafter is the description of the process transforming the resistance into initiative illustrated with excerpts from the above storytelling (section IV-2-3):

- Elements of expression of the fear:
  "Little by little, he was informed of the content of the session and he tried to prove that the associated workload could not be achieved from a one-day training session […] the following nominal phase would not work with only 2 trainers. The resistor argued that it would not work without the support of the researcher, and this several times during the exchange."
- Analysis of the possible sources of fear:
  Two assumptions came to light […]i)a potential increased workload for the trainer […] and ii)the possibility that the trainer might be asked to manage collective debriefing of simulated situations for which one could assumed he felt incompetent (in fact, at this stage of the exchange this was in fact what had been expected: field simulator trainers were supposed to conduct the collective debriefing session).
- The transformation of the project:
  […]. He was thus given details insuring that a Human Factors Consultant would support the 2 trainers during the forthcoming nominal phase and that debriefing would be the unique responsibility of the process trainer and consultant, not that of field simulator trainers."

Indeed, before this exchange, it was planned that the field simulator trainers would manage the collective debriefing of the simulated situations. This choice had two objectives: enhancing the field simulator trainers' pedagogical competencies and limiting the pedagogical teams at 2 trainers; i.e. the same resource than for the 2015 CLIG sessions. It was finally decided that a Human Factors Consultant would be present to support the 2 trainers in the forthcoming nominal phase and that the debriefing would be the exclusive responsibility of the process trainer and the consultant. This adjusted choice would remain the field simulator trainers' pedagogical competencies at the same level and would increase resource needed when compared with the 2015 CLIG sessions. However, as far as the Training Center is concerned, there would be no change as the additional resource would be a Human Factors Consultant from the NPP. This approach consisting in trying to identify the resistors' fear is not just a means to defuse the resistance. It is a way to admit that the resistor's fear is real for a good reason and that this reason must be taken into account by the innovator: it is a way to take into account the person in the project and to integrate their own perspective. For this reason, a debriefing was undertaken with the field simulator trainers to have a shared reflexive analysis of the meeting that contributed to defuse the resistance and adapt the project. The conclusion was that finally the project cannot be the "innovator's baby", it is a living process that is also fostered all along its design by the resistors' contribution.

This transformation process matched and confirmed Professor Bauer's suggestion (Bauer, 2001c) if we consider the trainers as users of the simulator: the unblocking of the situation requires analysing the contribution of resistance in relation to the variation of the users' benefits in a systemic approach in order "to understand resistance in relation to its effects [rather] than to its stimuli" (p113). For this aim, designers must be able to pay attention to users' criticisms and be prepared (and able) to reinvent the project (p118). This process also meets Muo's proposal (Muo, 2014: 105) emphasizing that "Resistance is a critical source of innovation as it encourages the search for alternative methods and outcomes and thus synthesizes any conflicting perspectives that may exist." We might extend this statement with the proposal that innovation is innovating per nature and may have this intrinsic character reinforced when tackling resistance that forces the innovation to become even more innovative when searching alternative solutions.

As described in section IV-2-3, this change had a direct effect on the resistance: resistance defusing. However, even if the "defused resistor" became opened for discussion, he did not abandoned his leitmotiv regarding factors of impediment for CLIG sessions in general: “Nevertheless there was still an underlying desire to underline the trainees’ ill will as a constant factor responsible for the difficulty in managing these sorts of training sessions correctly.” This point thus remained to be worked later.

Reading Professor Bauer’s analysis before having the face-to-face exchange with the resistor prepared the PhD researcher to be ready to change something. All the requirements to manage resistance to innovation made the meeting cognitively loaded. At the same time, the PhD researcher had to:

- present the 2016 CLIG session project,
- manage the hostility of the interlocutor with diplomacy,
- undertake a meta-analysis of the discussion to detect clues regarding the interlocutor’s fear(s),
- undertake a meta-analysis of the discussion to make a fast decision regarding what might be the solution to neutralize the interlocutor’s fear(s),
- identify the appropriate point of the exchange to introduce the topic that would transform the resistor into initiator.

A final point must be highlighted to conclude this contribution about the theory of resistance to innovation to the present research: Professor Bauer’s work was developed on the basis and considering resistance to innovation at a macroscale level: resistance in society. In the present study, the demonstration was done that Professor Bauer’s work can be applied at a microscale level, this of a company.

A classical analogy mentioned in the theory of resistance to innovation is that with acute pain (see for example: Lawrence, 1954; Bauer, 1991, 2017): “Resistance affects socio-technical activity like acute pain affects individual processes': it is a signal that something is going wrong; it reallocates attention and enhances self-awareness; it evaluates ongoing activity; and it alters this activity in various ways to secure a sustainable future” (Bauer, 2011a,: 3). Adopting this perspective, the innovator does not apprehend resistance like a barrier (classic approach of the Field Theory; see Frank, 1944; Lewin, 1947) but as an internal signal (approach of the Self-active theory; see Cranach et al., 1982; Luhmann, 1984) and the manifestation of resistance is not a counterforce by a self-monitoring subsystem. The development of the situation may then not be seen in a binary perspective win-loss but co-constructivism perspective with co-evolution of two systems (Bauer, 1991). It appears clearly that the two approaches portray two different landscapes of the same context thus entailing two different possible attitudes for the innovator: the former promotes or prepares confrontation whereas the latter advocates for an evolutionary co-construction by shifting “the interest from individual dispositions to the effects of resistance on the project” (Bauer, 2011: 119).

In the light of the “acute pain” analogy, the framework adopted to deal with resistance applying Professor Bauer’s work (2011a, b, c) is revealed in an overall strategy based on the Self-active theory. Forecasting what might have happened if the context had been managed in a confrontational perspective, the first assumption is that, to reach the same results, more energy should have been spent (e.g. further negotiations with the field simulator trainers to obtain material or special preparation of equipment) and the second assumption is that the results would have been plagued by their ill will. Bauer’s strategy presents the benefit to keep people working together.

Field experiment: Un. Hospital of Angers, France / radial puncture

For this field experiment, questionnaires were used to assess the motivation and the stress of the trainees; the scores obtained need a few comments.

The fact that the MSLQ scores (Table 39, section IV-2-4) showed an effective commitment of the two groups of trainees in the training session is not surprising: students volunteered to participate in the experiment because it gave them an additional opportunity to learn about simulation. The PhD researcher’s hypothesis mentioned in the “Material” section III-2-2 that the poor attendance of the first session was due to a lack of motivation was not verified: indeed students scheduled to participate in the first session cancelled in June 2016 having had to prioritize their activities in operating theatres and thus resulting in many participants dropping out. Beyond the objective acknowledgement of a real commitment through the MSLQ, direct observations during training sessions had confirmed this trainees' state of mind.

The ALES questionnaire for self-assessment of the stress gave quite interesting information regarding the type of stress perceived (Table 40, section IV-2-4). It was noted that, for a similar overall level of stress in the two groups, the contribution of stress due to positive excitement (resp. constraint) had significantly increased (resp. had been lessened) from the classic session to the restructured session. No data permit to explain the positive effect observed; however, we may form the hypothesis that the restructured session enhanced the students' self-confidence when compared with the classic session.

This might also have contributed to avoid trainees experiencing a state of stress resulting in a reduction of their cognitive capacities as demonstrated hereinafter.

There are two main kinds of mental stress: short term (or acute) stress and chronic stress (see for example the studies of Maslova et al. (2002) who studied the effect of chronic stress or studies of Schubert et al. (2009) who compare both kinds of stress). The stress that we addressed here was short term mental stress provoked by the one-off assessment on simulator. For short term mental stress perceived in simulation training, results presented in previous works (Fauquet-Alekhine et al., 2011b, 2014b) demonstrated that Yerkes & Dodson's bell curve could draw the relationship between task performance and stress due to constraints (Yerkes & Dodson, 1908; see Figure 56).

Yerkes & Dodson's bell curve was discussed in previous studies (Fauquet-Alekhine, 2012, 2014) and divided into three main Human Functional States (HFS) on the basis of the concept introduced by Leonova (2009):

- the left part is linked to a HFS of positive state of stress or stable cognitive state, where performance rises with the stress,
- the central part reflects a HFS of transience (transient state) for the subject in terms of stress effects, where performance has raised with stress until a given stress threshold beyond which the variation is inverted,
- the right part concerns a HFS of negative state of stress or potential cognitive deficit state, where stress tends to put the subject in a cognitive deficit state, reducing the subject's capacity to fully use his/her cognitive resource and making performance decreasing.

These HFS are drawn on the graph presented on Figure 56.

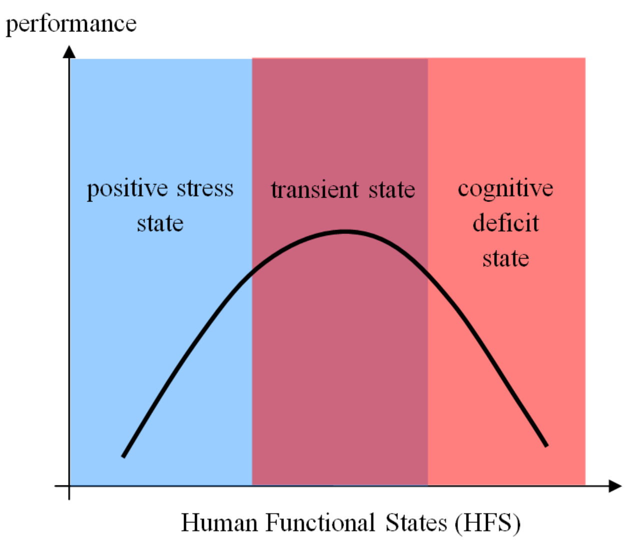


Figure 56: Human Functional States (HFS) divided into three main parts: i) central part: transient state for the subject in terms of stress effects, ii) left part: positive state of stress, iii) right part: potential cognitive deficit state.

The present study provides such data: performance was assessed through the performance score and short term mental stress due to constraints was self-assessed through the ALES constraint score of the ALES questionnaire. In order to draw performance score vs ALES constraint score and gauge whether the data might match this theory or not, the two cohorts of trainees were considered together. Performance scores and ALES constraint scores were averaged per unity interval on ALES: an average score was calculated for subjects whose ALES constraint score was between 0 and 1 and the associated averaged performance score was calculated using the related individual performance scores; the same was then done for interval 1 to 2 and so on. This was done in agreement with researchers' findings showing that, for these sorts of approaches, averaged data might help lessening bias due to individual characteristics (see for example Berton et al., 2015).
The final set of data is given on Figure 57, fitted by the polynomial least-square curve.

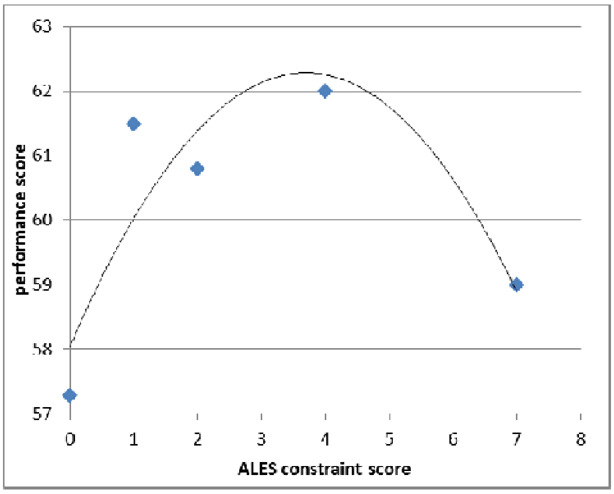


Figure 57: Average performance vs average stress due to contraint for trainees experiencing performance assessment on high fidelity simulator for radial puncture (all sessions together) fitted by a bell-shaped least-square curve .

The resulting fitting curve matched clearly the expected theoretical bell-shaped curve (r=0.88, p<0.0001). It is interesting to notice that most of the points lie in the positive stress state part of the curve. However, this estimation may be more accurate with a mathematical approach: the equation of the least-square fit curve y=f(x) on Figure 57 is second-degree polynomial of type:

$$y = ax^2 + bx + c$$

with:

$a = -0.31$

$b = +2.3$

$c = +58$

When derivating the function and equaling to zero, y=f(x) gives the value for the extremum associated with the stress threshold (peak of the bell curve); here:

$$\frac{dy}{dx} = 2ax + b$$

The value of the extremum is given by:

$$\frac{dy}{dx} = 0 \iff x = \frac{-b}{2a}$$

and the stress threshold is thus s_{max}=3.71 on ALES. This means that all subjects whose ALES constraint score was higher than 3.71 were in the potential cognitive deficit state part of the curve (Figure 56).

When considering the two cohorts, the proportion of trainees whose stress due to constraint overpassed s_{max} was:

- 36.4% for the classic session,
- 16.7% for the restructured session.

This finding shows that, by reducing the stress due to constraint, the restructured session helped trainees to avoid the HFS part corresponding to a potential cognitive deficit state.

To summarize the results from the classic session to the restructured session for this field experiment:
- Same motivation score on MSLQ,
- Average performance score increased by more than 13% with a standard deviation which was more than halved and a percentage of trainees whose score was over 90% of the maximum score multiplied by more than 5,
- Similar level of stress on ALES but a significant transformation of the nature of stress, changing from constraint to excitement,
- A reduction of trainees concerned by a potential cognitive deficit state due to stress from 36.4% to 16.7%.

The restructured session was thus more efficient overall than the classic session.

Here again, regarding the significant improvement of operational performance at the end of the SimS, it must be noted that, although the contribution of the SEBE/SPEAC method was clearly demonstrated by providing relevant and exhaustive input data for the training program and probably contributing to make the SimS more efficient from a pedagogical standpoint, the success of the training sessions resulted of an adjusted combination of several components among which especially, for this field experiment, the application of the 7S2P debriefing. As for the above field experiments, the main contributions of the 7S2P debriefing was the reflexive analysis and the projective perspective (see section II-4-1).

Figure 55 (section IV-2-4) shows that however a few points remain to be improved. After exchanging with the trainers at the Medical Training Centre, we concluded that some of these residual issues might be corrected in future training sessions using a full-scale simulator with an actor as patient; this might contribute to enhancing the relationship physician-patient and would contribute to force the improvement of the physician-patient exchanges including identification and consent.

A final comment is worth mentioning regarding the contribution of the SEBE/SPEAC protocol applied in this field experiment. This addresses the way the final 28-item check-list was elaborated. When presenting the results, we explained that the SEBE/SPEAC outcome matrix was used to identify what should be expected from the trainees resulting in a 52-item check-list, then reduced to a final check-list was 28 items when taking into account the fact that the session was for initial training, the specifications of the simulators and the duration of the session. For example, regarding “initial training”, the observable “Stops or adjusts automatic monitoring / automatic blood pressure measurement” was withdrawn because it was estimated better for the students to focus on the fundamentals of the activity’s technical nature; regarding “specifications of the simulators”, the observable “Selects the pulse from different sites (radial or other, right or left according to previous criteria” was withdrawn because the simulators presented only one site of puncture; regarding “duration of the session”, the observable “Prepares exhaustively the equipment” was withdrawn because it was preferred the students work on the puncture itself since, to prepare correctly the equipment, they first had to know exactly how to carry out the activity in order to help them to know the equipment and why they need it.

As announced in the previous section “Field experiment: Chinon NPP-EDF SA / measuring neutronic parameters through EP-RGL4”, the adaptation must take into account the characteristics of the targeted activity (what are the overall competencies), the characteristics of the trainees (novices or experienced, engineers or others) and the characteristics of the simulator available as described by Samurçay & Rogalski (1998) (see Figure 13 section II-4-2). The final comment worth mentioning here is that, doing so, the SEBE/SPEAC output matrix was used to develop the assessment grid of the activity in an easy, straightforward and fast way (one item in the matrix gave one or two simple observables). It thus puts in light another quality of the SEBE/SPEAC method in the field of training evaluation.

IV-2-6 The SEBE/SPEAC method, the training program performance and its modelisation

IV-2-6-a Performance

The SEBE/SPEAC protocol has been developed with the aim of improving competencies of workers. For each activity analysed, it provides a matrix {fields of competencies vs Knowledge & know-how} (see Table 17) used for the design of the training program and the identification and the selection of pedagogical goals.

As noticed all along the presentation of the results from the field experiments in the previous sections (from IV-2-1 to IV-2-4), the protocol alone does not allow improvement of a training program: if the structure and the means for the program are not adapted to the goals for example, any input data will not help any improvement. For "Application of RP" in NPP, the success of the training sessions resulted of an adjusted combination of several components among which especially the use of sub-cams during the simulated situations and the application of the 7S2P debriefing. In addition, the management had also set up the DAL system (configuration activity file) supervised by the management which strengthened the implementation of this training program in ROS. For the "Hydraulic configuration" training (CLIG sessions) in NPP, the successful adjusted combination included especially the application of decontextualization during the simulated situations and the application of the 7S2P debriefing. For the "Radial puncture" training in hospital, the successful adjusted combination took especially benefits of the application of the 7S2P debriefing. These findings advocate for looking at the way these different components may be optimally organized within a training program in the framework of the professionalization strategy of a company.

When considering the literature review, one of the model integrating all these components at the best and suggesting the associated organizational pattern in the model of Kolb (see Figure 12; see Kolb's Experiential Learning Theory model (ELT model) in Kolb, 1976; 1984; Kayes, Christopher-Kayes & Kolb, 2005). However, Kolb's model does not integrate the effect of the input data associated with the reference situation as suggested by Samurçay & Rogalski (1998) (see Figure 13). We assume that combining both models might shed light on the way mobilized competencies are elaborated in simulation training. This will be discussed in the next section.

Beside the identification of the components that favour performance increase through training, a crucial point, especially for managers of sociotechnical systems, is the performance assessment. All along the sections presenting results, performance was assessed at different levels: that of the trainees' perception, that of the activity performance in SimS and that of consecutive safety results associated with the performance in ROS. All these different levels for training assessment were integrated in a well-known model developed by Kirkpatrick & Kirkpatrick as a four-level pattern structured to evaluate training programs at different stages of training (Kirkpatrick & Kirkpatrick, 1994, 2005, 2007).

- Reaction level assesses the trainees' satisfaction (what they thought and felt about the training).
- Learning level assesses the resulting increase in competencies and change in attitudes.
- Behaviour level assesses the transference process between training the following ROS. It is a post-training evaluation while trainees are carrying out the job, usually through observations.
- Results level assesses the final resulting performance in ROS and may address productivity, cost or safety for example.

Following the early work of Kirkpatrick & Kirkpatrick (1994), other authors have suggested an additional fifth level of evaluation. Phillips (1996) has argued for a fifth level in terms of:

- Return on Investment (ROI): based on the comparison of the gain (Results level) to the overall costs of training.

The ROI is calculated as follows:

$$ROI=(G_i-C_i)/\ C_i$$

where:

- G_i: gain from investment
- C_i: cost of investment

A positive ROI refers to a positive effect of the training program conversely to a negative ratio and the higher is the ROI, the more efficient is the training program. Estimation how high must be the ratio to be considered as a significant ROI depends on the expectations of the sociotechnical system considered.

All these different level cannot always be assessed. For example, we saw that the "results level" could not easily be assessed for the field experiment "radial puncture". It does not mean that it is possible, but in this case, it seems that the energy to invest in order to obtain a reliable assessment of this sort would be disproportionate when compared with the final reliability of the data due to the current organization of French hospitals. This should be devoted to a specific study out of the PhD framework. Another field experiment for which the "results level" is not accessible is this of the "Hydraulic configuration" training in NPP: despite an adapted organization to provide such an assessment, data are not yet available since the training sessions have not yet reached their nominal configuration. Nevertheless, as we shall see, this may be estimated. The only field experiment for which the "results level" is available is that of "Application of RP".

In the domain of training assessment, it is worth pointing out that the Kirkpatrick model should include an additional level prior to the others: an "input data" level assessing the relevancy and the completeness of elements available and taken into account to design the training program. Indeed, as it was shown during the experimental and applicative test segments of section IV-1-1-d, Table 20 and Table 21, this contribution to the training program may differ greatly from one method to another.

Regarding the ROI, as the ratio is based on the "results level", our data only allows its calculation in the case of the field experiment "Application of RP" in NPP: section IV-2-2 provided a reliable evaluation of the gain obtained in the months following the achievement of the training program. The calculation considers investment costs (mainly that of training) and avoided costs.

Regarding the investment, the cost for training the teams for the pairs of units of the NPP was 9.8k€ related to a 3.5h. session calculated as follows:

- 2 trainers : 3.5x2x0.025k€=0.175 k€
- 8-member team including:
    - 2 team managers: 3.5x2x0.025k€=0.175 k€
    - 2 pilots: 3.5x2x0.02 k€=0.14 k€
    - 4 technicians: 3.5x4x0.015 k€=0.21 k€
- the cost per team was: 0,175 + 0,175 + 0,14 + 0,21 = 0,7k€,
- the cost for 7 teams per pair of units was 4.9k€,
- the cost for 14 teams for the NPP was 9.8k€.

The average hourly gross salaries giving an image of the cost for the company were calculated by the Human Resource Dept. over the NPP personnel per position.

The avoided cost was calculated by adding the cost induced by a RP safety event in terms of loss in production and cost for analysis.

The Operations teams' number of RP safety events decreased by 30% (3 events) from mid 2014-mid 2015 to mid 2015-mid 2016. This reduction by 3 events corresponded to avoiding expenditure equals to 3006k€ since per event it is 1002.12k€ related to:

- the time necessary to undertake the event analysis involving the event reporter (80h to write the analysis report) and the contributors to the event (2h. meeting for those whose actions led to the occurrence of the event):
    - for the reporter: 80hx0.025k€=2k€,

    - for the average 3 contributors of the event met for analysis during 2h.: 2hx3x0.02k€/h => 0.12k€ per event,
- the average production stop due to RP safety events is 1 day for 1 reactor. This data was calculated by averaging the total number of days without production due to RP safety events at Chinon NPP over 3 years, from mid 2013 to mid 2016. This statistical approach is necessary insofar as it is impossible to predict which event will give rise to a loss of production and in which proportion. According to the Safety Project Manager of Chinon NPP, 1 day production for 1 unit is 1 M€; the manager of the Accountancy Department said it might be a bit more. Here the value of 1M€ is kept.

Hence the net gain was 2996k€ and the return on investment was:

ROI = (3x1002,12-9,8) / 9,8 = 305%

These results may be extrapolated to estimate what might be the performance improvement if all the operational professions would be concerned by the training method.

Regarding the investment, the cost for training the Operations teams and the operational teams for the pair of units of the NPP would be 9.1k€ including 4.9k€ for the former (as calculated above) and for the latter 4.2k€ related to a 3.5h. session calculated as follows:

- 2 trainers : 3.5x2x0.025=0.175 k€
- 7-member team including
    - 1 team manager: 3.5x1x0.026k€=0.091 k€
    - 2 front managers: 3.5x2x0.02 k€=0.14 k€
    - 4 technicians: 3.5x4x0.014 k€=0.196 k€
- the cost per team would be: 0,175 + 0,091 + 0,14 + 0,196 = 0.6k€,
- the cost for 7 operational teams per pair of units would be 4.2k€.

The average hourly gross salaries giving an image of the cost for the company were calculated by the Human Resource Dept. over the NPP personnel per position. All possible operational teams must be considered (estimation: 7 per pair of units) as it is impossible to forecast which profession will be involved in a RP safety event occurrence.
The investment also incorporates two subjective video recording systems the cost of which (1k € in 2016 for both) decreases every year and can be considered negligible compared to the cost of training.

Regarding the avoided cost, assuming a decrease by 30% for the RP safety event of the NPP as this was observed for the Operations teams, the annual number of RP safety events would move from 17 to about 11 (data based on the annual safety analysis: Fauquet-Alekhine et al., 2016e). This reduction by 6 events would avoid expenditure equals to 6012k€ since per event it is 1002.12k€

The net gain for the NPP would thus be about ((6x1002,12-9.8x2) = 5994k€
with a return on investment:

ROI = (6x1002,12-9.8x2) /(9.8x2)= 329%

The forecast for gain extended to the whole fleet of EDF SA in France, including 19 NPP gathering 58 units gives:

- a cost investment for training equals to 29 pairs of units x 9.1k€ = 263.9k€ for the whole fleet per year,
- a gain in terms of RP safety events, analysis and related production stops, is estimated to a third of the progress obtained at Chinon NPP (as Chinon NPP was ranked in the last third of the fleet in terms of safety results before 2015): for Chinon NPP, data is 6 RP safety events meaning 3 for one pair of units. A third is 1 event per pair of units. The fleet has 29 pairs of units. The estimated avoided events are 1 x 29=29.
- the expenditure per event being 1002,12k€, the estimated avoided expenditure 29x1002,12 = 29061€,

- a final net gain equals to 29061-263.9 = 28797k€ per year,
- an associated ROI=(29061-263.9) / 263.9= 109%.

It might be considered that the cost of training concerns only the first year but this is wrong: due to the renewal of the staff, the training program must be annual.

This calculation demonstrates the high added-value of the training program developed in the present study for the "Application of RP".

A similar reasoning might be applied for the CLIG training sessions devoted to Hydraulic Configuration improvement by using the economic model developed for "Application of RP" and accepting the hypothesis that the training program presented here should provide a decrease of related safety events by the same proportion. The activities potentially concerned by the improvement are Hydraulic Configuration and Lock and Tag.
The expected improvement in terms of safety event being 30%, as the annual safety analysis showed that 6 safety events per year might concern this kind of activities (see Fauquet-Alekhine et al., 2016e), the annual improvement is 1.8 safety events. The related cost is estimated to 0.3day of production per event. This data was calculated by averaging the total number of days without production due to Hydraulic Configuration and Lock and Tag safety events at Chinon NPP over 3 years, from mid 2013 to mid 2016. This statistical approach is necessary insofar as it is impossible to predict which event will give rise to a loss of production and in which proportion. According to the aforementioned economic model, 1 day production for 1 unit is 1 M€. The associated avoided cost is thus 543.8k€ per year for Chinon NPP and 2.92M€ per year for the whole fleet when considering an improvement for the feet reduce to third from Chinon NPP data. The cost for training being the same than for the Application of RP, the ROI for Chinon NPP is forecasted at 54% and for the fleet at 20%.

"In general, a good average return on investment would consist of a return that exceeds the average rate of return stock market." (Wall Street Survivor, 2016). When extrapolating this financial consideration to training, this means that the assessment of the ROI efficiency is relative to which gains training programs may provide in the company or, to a larger extent, to which gains training usually provides in companies.
This sort of evaluation is very difficult as it is always easier to demonstrate a result on the basis of actual consequences of what was not done rather than on the basis of what was likely avoided due to an action plan. In addition, updated data is not easy to find. A report published in 2003 (IEA, 2003) provided ROI for energy industries worldwide which was estimated at 9%; the problem is that, even though it gives an insight of the equivalent "average rate of return stock market" for electric industries, it includes all industries worldwide and not just EDF SA, all fields of investment and not only training, and provides data over 10 years. Obtaining reliable examples of ROI calculation for training from companies is really difficult. In her revue, Bartel (2000) gathered 26 training cases in companies with associated ROI calculation. Among them, she selected cases from econometric analyses (tables 1 & 2 of her paper), rejecting the others due to huge bias affecting calculations e.g. (subjective evaluation of trainers, confusing trainees' satisfaction and operational results, monitoring operational results over a too short period or too few workers, selecting the best employees (p.519)) and artificially pushing values towards extremes of several thousands. However, according to the author, "the estimated rates of return from this literature depend on the assumption regarding the skill depreciation rate. Assuming that skills depreciate 5 percent per year, the estimated rates of return range from 7 to 50 percent. […] Unfortunately, few companies calculate the ROI in employee training […] and […] use faulty methodologies" (p.522). In the light of Bartle's analysis, we may conclude that the ROIs estimated in the present study may be considered quite satisfactory but that there values should be nevertheless reduced due the multifactorial context of ROS making it impossible to isolate the contribution of the training program on the operational performance. For example, considering the "Application of RP" on NPP, we mentioned that training was combined with the effect of the management's sustainment which contributed assuredly to the performance increase.

A similar econometric approach might be worth to be carried out regarding the medical field experiment. Unfortunately, the organisations of French hospitals do not provide complication feedback as nuclear industries. The scientific literature only mentions data for Anglo-Saxon hospitals addressing medical issues with high level of complications, far from what may happen after a difficult or failing radial puncture. Yet the consequences are not negligible. The head manager of the Medical Training Center of Angers explained that several tens of radial punctures are undertaken per day in a hospital (all departments included). No data is available regarding the number of radial punctures failing; however, as a first approximation, in the opinion of the head manager, one case over ten is not successful at the first attempt. This implies a double cost regarding the equipment used and the time spent by the medical personnel; it also implies an additional involvement of the medical personnel if supplementary care is needed due to patients' added pain. Therefore, it may be assumed that an improved occupational training program for radial puncture might lead to an avoided cost of several tens of thousands of euros per years, but this stays at the stage of hypothesis.

IV-2-6-b Modelling simulation training

All the field experiments presented in the section IV-2 regarding elaborating competencies in high risk industries followed the same framework: analysing the ROS using the SEBE/SPEAC method, designing the simulation, training in simulated situations with a 7S2P debriefing for each participant including a reflexive analysis of the situations and a mental projection on future ROS, and finally an application in ROS. This framework respected the organizational pattern of the Experiential Learning Theory model of Kolb (see Figure 12 section II-4-2 and Kolb, 1976; 1984; Kayes, Christopher-Kayes & Kolb, 2005) and integrated the simulation conditions described by Samurçay & Rogalski (1998) (see Figure 13 section II-4-2) through the steps "analysing the ROS using the SEBE/SPEAC method" and "designing the simulation". This framework for occupational simulation training showed its efficiency through the performance assessments presented above. Therefore, modelling this framework should be of great interest.

As mentioned through this description, the framework used complied with ELT Kolb's model (Experiential Learning Theory model) with however one difference or one precision: there is not one concrete experience but several, at least the concrete simulated situation experienced by the trainee when trained in simulation and the following concrete ROS experienced after training when applying the competencies. This entails a cyclic and excursive conception of the ELT model as shown Figure 58.

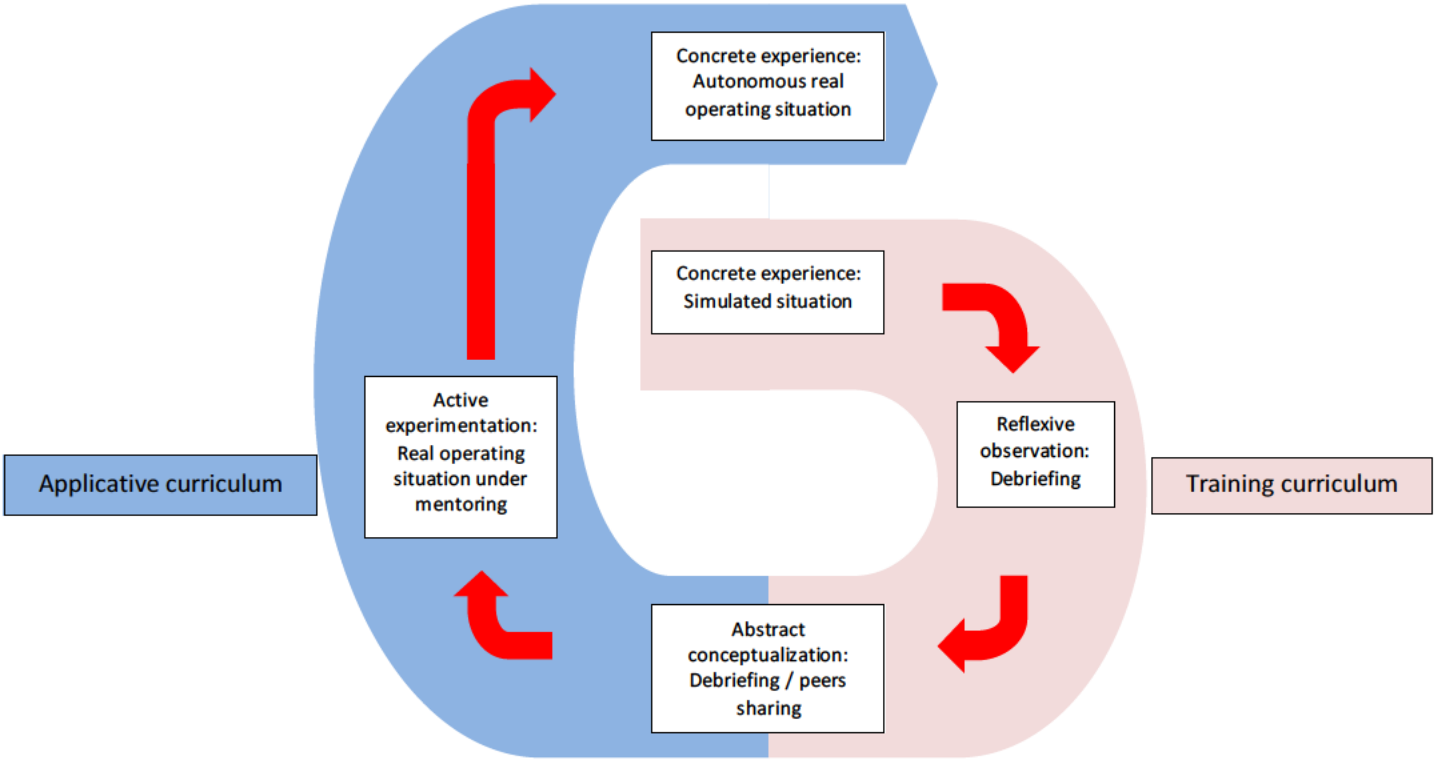


Figure 58: Example of excursive cycle of the professional training process applying Kolb's ELT model.

The professional training process modelled by Kolb's ELT gives an insight of the systemic dimension through the excursive cycle. Two occupational curricula may be distinguished within the cycle: a training curriculum (which may be concretely a simulation training session) related to the simulated situations where subjects have the position of trainees, and the applicative curriculum involving subjects as workers in the real operating situations.
As written just above, Figure 58 is just an insight of a professional training cycle. The excursive cycle may adopt different shapes depending on different factors which may be identified through the analysis of the system design. The set of Figure 59 illustrates other possible patterns of excursive cycles.

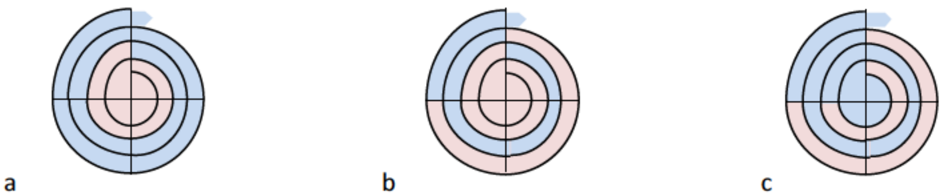


Figure 59: Different possible patterns for excursive cycle of the professional training process applying Kolb's ELT model.

Considering a given socio-technical system such as an industrial plant, Figure 59a could illustrate the case of a newcomer in the company involved in an initial training period followed by a mentoring and then an autonomous involvement.
Figure 59b could illustrate the case of a newcomer in the company involved in an initial training period followed by mentoring and a new training period followed again by mentoring and then an autonomous involvement.
Figure 59c could illustrate the case of a newcomer entering the company and coming from another similar company so that this newcomer is in fact experienced and does not need any initial training period. This "experienced newcomer" thus begins by mentoring followed by a training period in order to update his competencies followed again by mentoring and then an autonomous involvement.

However, Samurçay & Rogalski (1998) (see Figure 13 section II-4-2) highlighted the key role of the reference situation, this which the SEBE/SPEAC protocol intends to describe and about which the present study has emphasized the contribution in the training process through the output matrix provided. It should thus be interesting to integrate Samurçay & Rogalski's model within the excursive cycle presented on Figure 58. Doing so, we introduce the reference situation as an intermediate concept between ROS and SimS and we obtain the excursive experiential learning cycle presented on Figure 60 that models how 'mobilisable competencies' are elaborated through simulation training in high risk industries. The reference situation is experienced-based and gives rise to the simulated situation through didactic transposition.

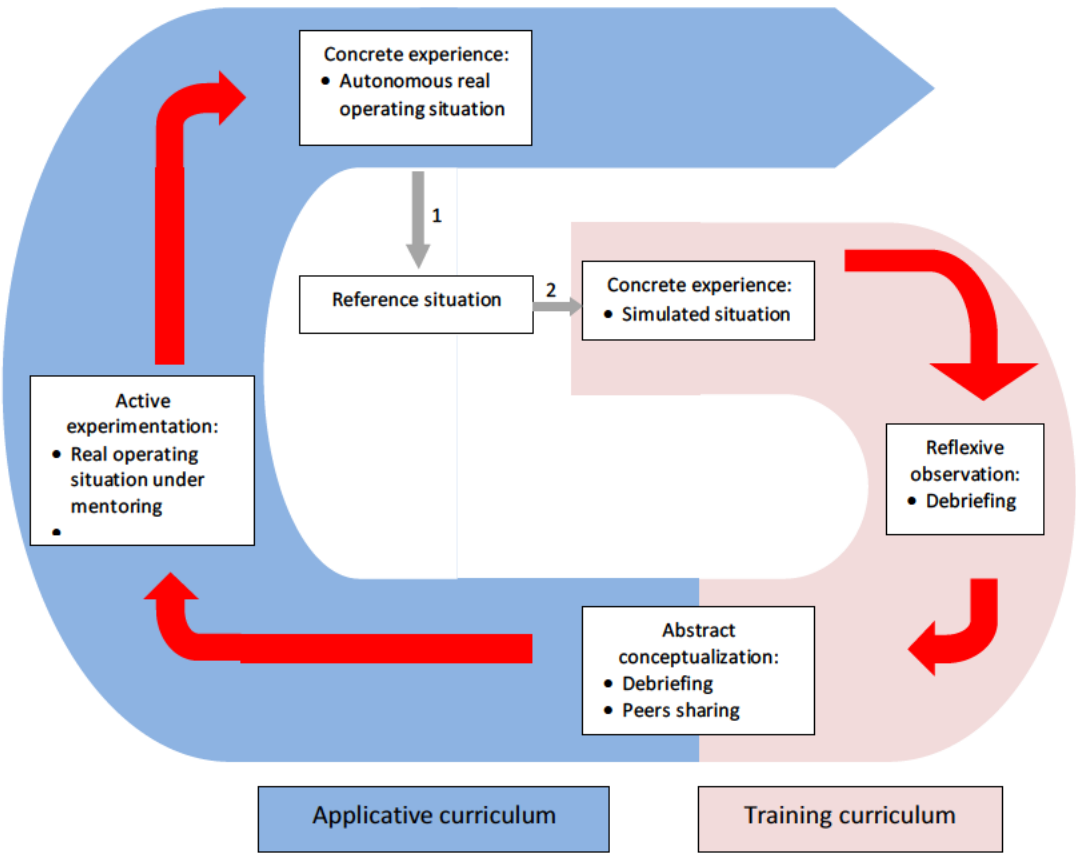


Figure 60: The excursive experiential learning cycle model. Arrow #1: the reference situation is experienced-based. Arrow #2: didactic transposition.

Conversely to Samurçay & Rogalski (1998) (see Figure 13) or Kolb'model (see Figure 12 and Kolb, 1976; 1984; Kayes, Christopher-Kayes & Kolb, 2005), the excursive experiential learning cycle model presents the advantage to describe each of the levels for assessment identified in the 6-level Kirlpatrick's extended model developed above. These levels are:

- Input level assesses the relevancy and the completeness of elements available and taken into account to design the training program.
- Reaction level assesses the trainees' satisfaction (what they thought and felt about the training).
- Learning level assesses the resulting increase in competencies and change in attitudes.
- Behavior level assesses the transference process between training the following ROS. It is a post-training evaluation while trainees are performing the job, usually through observations.
- Results level assesses the final resulting performance in ROS and may address productivity, cost or safety for example.
- Return on Investment (ROI): based on the comparison of the gain (fourth level) to the overall costs of training.

Figure 61 shows how these 6 levels are positioned on the 6-level Kirkpatrick's extended model:

- The Input level concerns the transition between the reference situation and the SimS in order to obtain a design for the SimS as relevant as possible.
- The Reaction level and the Learning level are positioned at the end of the training curriculum and confirm the new competencies targeted in SimS.
- The Behavior level is positioned in the first ROS following SimS; in particular, it gives a picture of the effectiveness of the projective perspective as defined for the 7S2P debriefing (see section II-4-1). According to Kirkpatrick, this assessment is carried out during the 3 to 6 months following training; this may seems too long but as it is supposed to assess a change in behavior, several months may actually be necessary.
- The Result level is positioned far after the SimS in the Applicative curriculum since it comes after the previous level.
- as the ROI is based on an integration of the results, , it is makes sense after several months following the training session.

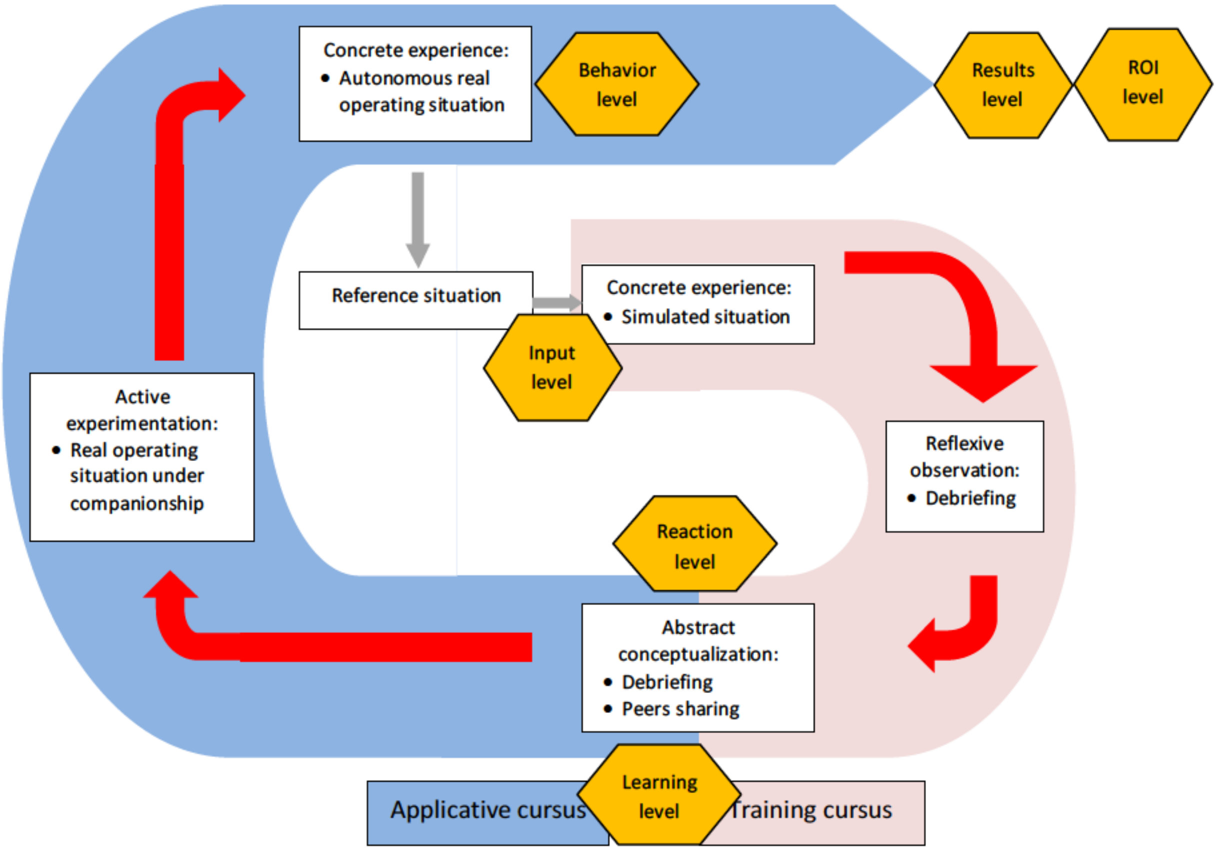


Figure 61: The 6-level Kirkpatrick's extended model and the excursive experiential learning cycle model.

Table 41 indicates how the field experiments of the present study were concerned by the 6-level Kirkpatrick's extended model by applying green color in the corresponding boxes. The case of the Periodical test EP RGL4 is a bit confusing since the SEBE/SPEAC method was applied in parallel to the SAT+descriptive-based method and only the latter gave rise to a training session; therefore the line is highlighted with light green.

The success of the project might be related to the degree of complexity of the organizational system in which it was intended to be implemented or perhaps should we write that some organizations were so complex that not all conditions could be met in the time given for the planned change to be implemented.

Table 41: Field experiments of the present study and the effectiveness of the 6-level Kirkpatrick's extended model.

	Input level (IL)	Reaction level (ReaL)	Learning level (LL)	Behavior level (BL)	Result level (ResL)	ROI
EPR pilots' training	no	no	no	no	no	no
Air Force novices' training	no	no	no	no	no	no
Periodical test EP RGL4	yes	no	no	no	no	no
Application of RP	yes	yes	yes	yes	yes	Yes
Hydraulic configuration	yes	yes	no	no	no	no
Radial puncture	yes	yes	yes	no	no	no

The field experiments that fell through were organizational systems involving 4 entities interacting with an entity external to this system contributing to the project falling through (see section IV-2-5). In the other cases of completed field experiments, the organizational systems were less complex as three or two entities only interacted:

For the University Hospital of Angers, the Medical Training Center with the LSE through the PhD researcher were in direct interaction with the hospital operations departments;

In the case of Application of RP in the French nuclear industry, the LSE with the PhD researcher were in direct interaction with the Operations departments only.

Therefore, on the basis of entities interacting in the framework of the project, three different configurations, drawn on Figure 62, were encountered: 4-part system, 3-part system and 2-part system.

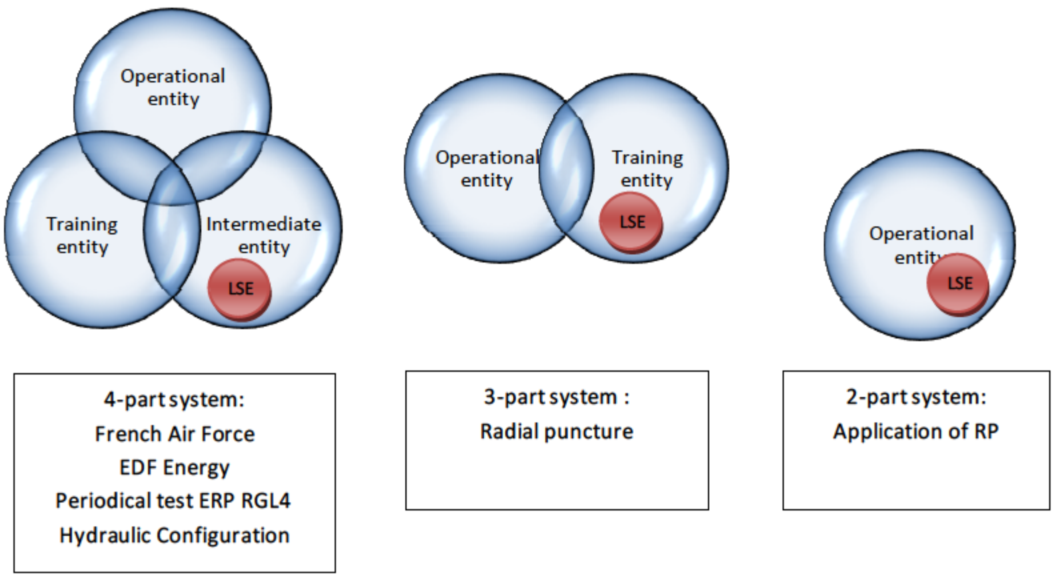


Figure 62: the different configurations of socio-organizational systems encountered during the present study.

When drawing the time needed to achieve the levels of the 6-level Kirkpatrick's extended model for the field experiments of the present study (Figure 63; times are given in the respective sections "Materials" and "Results"), it appears a clear difference between the 3-part systems and the others: when reading their respective storytelling, the 4-part systems are concerned by parallel or disconnected objectives and this makes decision making less straightforward. However, the cases available here are too few to permit a generalized conclusion: further experiments or more case should be considered for this aim.

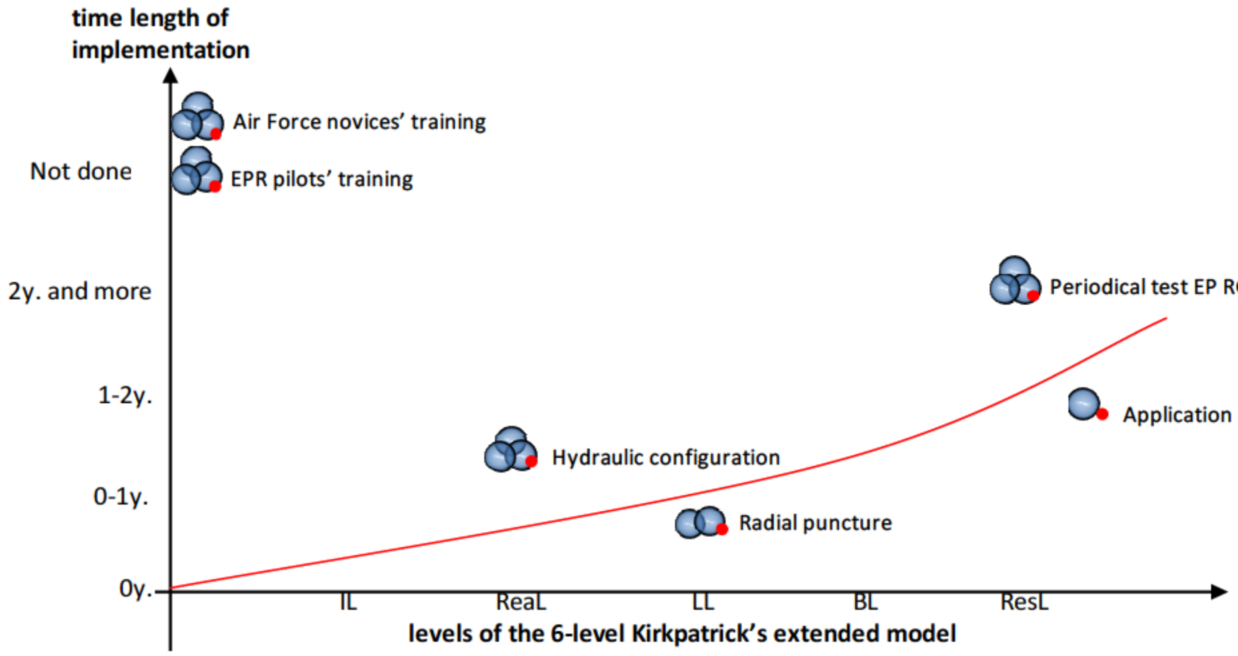


Figure 63: Time needed to achieve some of the levels of the 6-level Kirkpatrick's extended model vs these levels: (IL) Input level, (ReaL) Reaction level, (LL) Learning level, (BL) Behavior level and (ResL) Result level.

Limits of the excursive experiential learning cycle model

One of the limits of the excursive experiential learning cycle model based on Kolb's work (Kolb, 1984; Smith & Kolb, 1996) is that the learning styles of Kolb's model are not taken into account while they may influence training program performance. However, the way this factor have to be taken into account might be difficult to define since learning style fluctuates during the learning process (see for example Soflano et al., 2015) and since several theorizations of learning styles have been proposed: to give only two examples, Honey and Mumford (1992) identified activists (subjects prefer to use a trial-and-error method), reflectors (subjects prefer to analyze the task before attempting it), theorists (subjects prefer to listen to instructions and theories before attempting the task) and pragmatists (subjects prefer to learn from a demonstration); Dunn (2003) identified visual style (subjects prefer visual presentation of material, auditory style (subjects prefer to listen to the material) and kinesthetic style (subjects prefer to undertake physical activity and apply the material). Integration of this sort of factor in the excursive experiential learning cycle model, if relevant, needs further experiments.

To summarize discussions of section IV-2: The outcome of the SEBE/SPEAC method was used in the design of training programs. Four field experiments were obtained for application, three in nuclear industry and one in medicine.

Application performance was assessed in each case. For this aim, a 6-level Kirkpatrick's extended model was developed and applied:

- Input level assesses the relevancy and the completeness of elements available and taken into account to design the training program.
- Reaction level assesses the trainees' satisfaction (what they thought and felt about the training).
- Learning level assesses the resulting increase in competencies and change in attitudes.
- Behavior level assesses the transference process between training the following ROS. It is a post-training evaluation while trainees are performing the job, usually through observations.
- Results level assesses the final resulting performance in ROS and may address productivity, cost or safety for example.
- Return on Investment (ROI): based on the comparison of the gain (Results level) to the overall costs of training.

Application of the 6-level Kirkpatrick's extended model showed a high performance of the method used.

Results were then used to demonstrate the necessity for a model in order to better understand the process for elaborating competencies in collaborative activities through simulation training. Two existing models were combined giving rise to the excursive experiential learning cycle model mainly based on Kolb's work.

The main theoretical contribution of this application part of the research was thus to provide an innovative excursive experiential learning cycle model answering RQ2 for which performance assessment levels were identified with the help of the 6-level Kirkpatrick's extended model developed for the purpose. A secondary contribution was the demonstration that Bauer's Theory of resistance to innovation, developed at a macroscale level (society), could be successfully applied at a microscale level (company).

The research discussion ended in emphasizing how the training process performance could be sensitive to the size of the complex sociotechnical system considered: studied systems larger than 3 parts were concerned by parallel or disconnected objectives and this made decision making less straightforward. The analysis of this relationship might constitute a relevant perspective as research field for simulation training.

Chapter V - Conclusions

The present study originated from a general industrial problem to do with a social phenomenon of "skills drain"[24] (retired workers leaving companies *en masse* sometimes even before the recruitment of newcomers). This phenomenon impeding mentoring, managers are seeking innovative solutions to train new employees and ensure a satisfactory level of competencies, especially in high risk industries. From the industrial standpoint, in high risk industry, the general question addressed what makes operational professionals competent in collaborative work activities through simulation training. "Collaborative" and "simulation" are two words of importance as almost all work activities are collaborative and since simulation training (especially on full scale simulators) has become a crucial tool for professionalization in high risk industries.

The research questions (RQ) that arose from the original industrial question and the literature review were RQ1: How are competencies of experienced workers mobilized and how to access them? and RQ2: How are 'mobilizable competencies' elaborated through training in high risk industries? These RQ implicitly integrated the properties "collaborative" for activities and "simulation" for training.

Did we answer these questions and how did we do?

The flow chart on the next page summarizes the general process that was followed:

- firstly, a technique to collect relevant competencies in action was set up (accessing competencies);
- secondly, it was then tested whether that technique yielded better results, by designing training sessions based on the competencies collected and evaluating if training improved (how competencies can be elaborated through training).

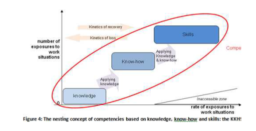
[24] "skills drain" not to be confused with "brain drain".

RQ1 : How are competencies of experienced workers mobilized …

… and how to access them?

RQ2 : How are 'mobilizable competencies' elaborated through training in high risk industries?

Definitions and relationship between knowledge, know-how, skills and competencies:
the KKHS synthesis.



Model for competencies in action:
selection of the 3-pole-based Le Boterf's model.

Test of Le Boterf's model with N=50 activities:
Emergence of the 4-pole-based SPEAC model needed to describe competencies in action.

Exploring the Cognitive Task Analysis paradigm leading to a Subjective Evidence-Based Ethnographic method (SEBE method).

Design of the SEBE/SPEAC protocol.

Design of the SEBE risk assessment protocol.

Test of the SEBE/SPEAC protocol to collect competencies.

Activity analysis in experimental test segment: N=5 SimS.	Activity analysis in applicative test segment: N=23 ROS.	Collaboration analysis in applicative test segment: N=15 ROS.	Comparison with 3 other methods: self-confrontation, SAT, SAT+descriptive method. Dependant variables: nb of KKH identified and cost.

Field experiments with specifically designed training sessions using the competencies collected with the SEBE/SPEAC protocol (in actual occupational training).

"Measuring neutronic parameters through periodical test EP RGL4" at NPP. Dependant variables: none; assessment based on qualitative comparison with classic training.	"Application of Reliability Practices" at NPP. Dependant variables: score assessing the Reaction and Results Levels (Kirkpatrick's model), ROI.	"Hydraulic configurations" at NPP. Dependant variables: score assessing the Reaction and forecasted Results Levels (Kirkpatrick's model), forecasted ROI.	"Radial puncture" at Hospital. Dependant variables: score assessing the Reaction and Learning Levels (Kirkpatrick's model).

Discussion and Conclusions

NB: KKH: Knowledge & Know-How
KKHS: Knowledge, Know-How & Skills
ROI: Return On Investment

It first appeared necessary to precise definitions and relationship between knowledge, know-how, skills and competencies. Facing the absence of general consensus in the literature, we finally suggested a summary of this issue that did not claim to be the truth but to present appropriate considerations regarding the problems addressed in the present study: competencies are considered as an overall concept designating knowledge, know-how and skills where knowledge is a prerequisite to know-how and skills; skills develop from know-how in action with experience, where “experience” means being exposed to situations several times and at a certain frequency.
The literature review then led us to conclude that a model for competencies in action was necessary to answer RQ1 and provided only one model complying with these requirements, Le Boterf’s model defining competencies as an interacting system of three poles, drawing competencies as a triangle: *Knowing to act, Wanting to act* and *Being able to act.*
However, after tests, the model revealed itself to be incapable of fully describing competencies in action. : the model could not integrate some of the motives making subjects involved in action, those designed by external conditions.
This gave rise to the development of an innovative model, the Square of PErcieved Action model (SPEAC model, Figure 64) complementing the triangle of competencies with the fourth pole *Having to act*.

[redacted]

Figure 64: The Square of PErceived ACtion model (SPEAC model).

The SPEAC model was then successfully tested (50 cases) and integrated in a protocol to access competencies in action. This was achieved after exploring the Cognitive Task Analysis paradigm leading to a Subjective Evidence-Based Ethnographic method (SEBE method) for our needs. The SEBE/SPEAC protocol was thus designed on the basis of the SPEAC model; it combined a first-person video recording of the activity followed by an in-situ subjective interview (replay interview). The protocol was tested for individual and collaborative activities at Chinon nuclear power plant in simulated situations (experimental test segment: N=5 situations: valves maintenance, block-watch around in control room for a reactor pilot, equipment identification in machine room for a field worker and hydraulic configurations for a pilot-field worker collaborative activity) and in real operating situations i.e. during shifts with Operations teams (applicative test segment: N=23 situations: hydraulic configurations, electric configurations, periodical tests and application of reliability practices).

For each work activity analyzed, the SEBE/SPEAC protocol showed significantly higher efficiency when compared with three other methods: higher number of explicit knowledge and know-how detected (from 1.44 to 17 times more), tacit knowledge and know-how identified while not detected with other methods and a reduction of the analysis cost by 30%.
The outcome of these methods was to provide input data for training programs in terms of competencies to be developed by trainees. Regarding analyses of collaborative activity, the concept of intersubjective structure of (non)collaboration was developed and applied on the basis of Gillespie’s Intersubjective Theory. It was shown how perspective-taking was a crucial factor for the collaborative activity performance: significant high correlation performance with job performance and main factor to explain job performance through a multiple linear regression analysis.

The main contribution of this part of the research was thus the design, test, evaluation and application of the SPEAC model (answering the first part of RQ1: how are competencies of experienced workers mobilized?), its integration in the dedicated SEBE/SPEAC protocol (answering the second part of RQ1: how to access them?) and the suggestion and application of the concept of the intersubjective structure of (non)collaboration (answering the implicit part of RQ1 regarding collaborative activities). In addition, an in-depth analysis of introspection during replay interviews was undertaken for the first time in the digital ethnography literature.

Then the outcome of the SEBE/SPEAC method was used in the design of training programs. Four field experiments were obtained for application, three in nuclear industry and one in medicine.
The first field experiment (at Chinon NPP) helped us to highlight areas for improvement regarding the training session designed by the Training Center for the activity "Measuring neutronic parameters through EP RGL4". The second field experiment (at Chinon NPP) permitted to design a new training program for Operations teams applying Reliability Practices, leading to a high level of satisfaction of trainees, to high improvement of activities in terms of safety indicators (42% higher than for other teams) and to a significant avoided cost (several k€ for Chinon NPP and a forecast of several tens of k€ if applied to the French nuclear fleet). The third field experiment (at Chinon NPP) permitted to design an innovative training program to replace training sessions (CLIG sessions) for hydraulic configurations which were rejected by trainees, members of Operations teams: the restructured sessions based on the applicative test segment results increased trainees' satisfaction by 17.2%. This restructured session was also positively assessment by an EDF national expert. The last field experiment (at the Medical Training Center of the University Hospital of Angers) improved trainees' competencies for radial puncture by 11% and the percentage of trainees whose score was over 90% of the maximum possible score was multiplied by more than 5. It also significantly reduced the negative effect of stress during training.

During this applicative period, several difficulties were encountered due to the inertia of the complex sociotechnical systems considered and, for one of them, due to resistance to innovation. The latter was the opportunity to apply Bauer's Theory of resistance to innovation and to show that, although developed at a macroscale level (society), it could be successfully applied at a microscale level (company).

In addition, the performance of the method had been assessed by an external entity: In November 2016, the WANO[25] peer reviewers spent two week at Chinon NPP checking in depth the process and the organization performances. They identified 12 areas for improvement and only 3 strengths among which the work done when applying the SEBE/SPEAC method on Reliability Practices in Operations teams (one of the four field experiments for application). This work was identified as demonstrating "a new, higher level of excellence that would benefit other plants in the industry to emulate [...] [and] should be considered as 'redefining' excellence" with a possibility to "likely drive change in the industry" (see appendix 27).

Test and application of the SEBE/SPEAC method was assessed in each case. For this aim, a 6-level Kirkpatrick's extended model was developed and applied:

- Input level assesses the relevancy and the completeness of elements available and taken into account to design the training program.
- Reaction level assesses the trainees' satisfaction (what they thought and felt about the training).
- Learning level assesses the resulting increase in competencies and change in attitudes.

[25] WANO is the World Association of Nuclear Operators. It gathers all industries worldwide providing electricity from nuclear energy. WANO undertakes periodically peer-reviews in NPPs with the help of internationally renowned experts. WANO's assessment always makes reference.

- Behavior level assesses the transference process between training and the following real operating situations. It is a post-training evaluation while trainees are performing the job, usually through observations.
- Results level assesses the final resulting performance in real operating situations and may address productivity, cost or safety for example.
- Return on Investment (ROI): based on the comparison of the gain (Results level) to the overall costs of training.

However, the 6-level Kirkpatrick's extended model could not be all applied for each case. It was depending on the research goal and the context.

For example:
Experimental and applicative test segments aimed at comparing the capacity of the SPEAC method to identify Knowledge and Know-how as opposed to other methods: the assessment on the Kirkpatrick scale was only possible at Input Level.
The "Periodical test EP-RGL4" field experiment did not give rise to implementation in training sessions but only comparative application: only the Input level was quantified and the Reaction level was qualified.
The field experiment "Radial puncture" did not provide assessment in real operating situations after training: only the Input level, Reaction level and Learning level were quantified.

Furthermore, the dependency on context meant choosing different forms for a given variable. This is why, for example, the performance variable for "Application of Reliability Practices" was a safety indicator whereas for "Radial puncture" it was a competencies-based score.

Table 42 summarizes at which level each case was assessed, which variables were used for this aim and which statistical tests were selected to validate the assessment.

Table 42: Overview of assessment variables and results per experiments

Contexts	Input level	Reaction level	Learning level	Behaviour level	Results level	Return on investment (ROI)	Dependant Variable(s) for assessment	Results	Statistical tests
Experimental test segment: N=5 SimS	X						Experiment restricted to analysis of work activity; No application in training session. Performance variables: ●ratio (KKH from SPEAC)/(KKH from other method) ●ratio (tacit from SPEAC)/(tacit from other method) Cost variable: ●ratio (man-days for SPEAC)/(man-days for other method)	1.44 to 17 29%/0% to 66%/0% 0.7 to 1	none
Applicative test segment N=23 ROS	X						Experiment restricted to analysis of work activity; No application in training session. Performance variables: ●ratio (KKH from SPEAC)/(KKH from other method) ●ratio (tacit from SPEAC)/(tacit from other method) Cost variable: ●ratio (man-days for SPEAC)/(man-days for other method)	1.9 to 24 17%/0% to 61%/0% 0.7	none
Field experiment: Periodical test EP-RGL4 (NPP)	X						Performance variables: ●ratio (KKH from SPEAC)/(KKH from other method) ●ratio (tacit from SPEAC)/(tacit from other method) Cost variable: ●ratio (man-days for SPEAC)/(man-days for other method)	3.0 50%/0% 0.7	none
		/					A qualitative comparative analysis was undertaken between what provided the Training Center session and what suggested the SPEAC-based analysis through observations and perception questionnaire (appendix 3)	qualitative	NA
Field experiment: Application of Reliability Practices (NPP)	X						Performance variables: ●ratio (KKH from SPEAC)/(KKH from other method) ●ratio (tacit from SPEAC)/(tacit from other method) Cost variable: ●ratio (man-days for SPEAC)/(man-days for other method)	18.0 17%/0% 0.7	none
		X					Perception questionnaire (appendix 8) providing a score from a coded Likert scale (range: –2; +2)	0.97 to 1.36	Cronbach α t-test χ^2
			X				Qualitative assessment at exit of the training sessions	NA	NA
				X			Assumed from the "Results level"	NA	NA
					X		Performance variables: ●Industrial safety indicator: proportion of improvement (%) ●Industrial avoided cost for one NPP ●Industrial avoided cost for the nuclear fleet	–30% 3 M€ 29M€	z-test
						X	Performance variables: ●ROI for one NPP ●ROI for the nuclear fleet (estimation)	305% 109%	NA
Field experiment: Hydraulic configuration (NPP)	X						Performance variables: ●ratio (KKH from SPEAC)/(KKH from other method) ●ratio (tacit from SPEAC)/(tacit from other method) Cost variable: ●ratio (man-days for SPEAC)/(man-days for other method	6.7 to 8.5 51%/0% to 54%/0% 0.7	none
		X					Two perception questionnaires (appendix 28) providing a score used to measu e trainees' satisfaction variation from previous training session to SPEAC-based session: ●CLIG Training Center questionnaire (Likert scale range: –1; +1) ●CLIG research questionnaire (Likert scale range: –2; +2)	0.86->0.93 0.27->0.96	Cronbach α t-test z-test
Field experiment: Radial puncture (Hospital)	X						No other analysis available for comparison.	NA	NA
		X					State variables: ●motivation through MSLQ (scale:1 to 7) - Extrinsic Goal Orientation - Task value -Self-Efficacy for Learning and Performance ●Stress through ALES (appendix 10) -constraint score M (SD) -excitement score M (SD) -overall score M (SD)	4.79->4.75 5.40->5.00 5.41->5.56 4(7)->2(2) 15(6)->18(4) 19(10)->19(5)	Cronbach α t-test
			X				Performance variable: ●score obtained according to the check-list made up of 28 items (max score=68; see appendix 11) used to measure trainees' performance variation from previous training session to SPEAC-based session M (SD)	55(6)->63(3)	Cronbach α t-test

KKH: Knowledge & Know-How
NA: Not Applicable

Results were then used to demonstrate the necessity for a model in order to better understand the process for elaborating competencies in collaborative activities through simulation training. Two existing models were combined giving rise to the excursive experiential learning cycle model mainly based on Kolb's work. The main theoretical contribution of this application part of the research was thus to provide an innovative excursive experiential learning cycle model answering RQ2 (Figure 65) for which performance assessment levels were identified with the help of the 6-level Kirkpatrick's extended model developed for the purpose.

The research discussion ended in emphasizing how the training process performance could be sensitive to the size of the complex sociotechnical system considered: studied systems larger than 3 parts were concerned by parallel or disconnected objectives and this made decision making less straightforward. The analysis of this relationship might constitute a relevant perspective as research field for simulation training.

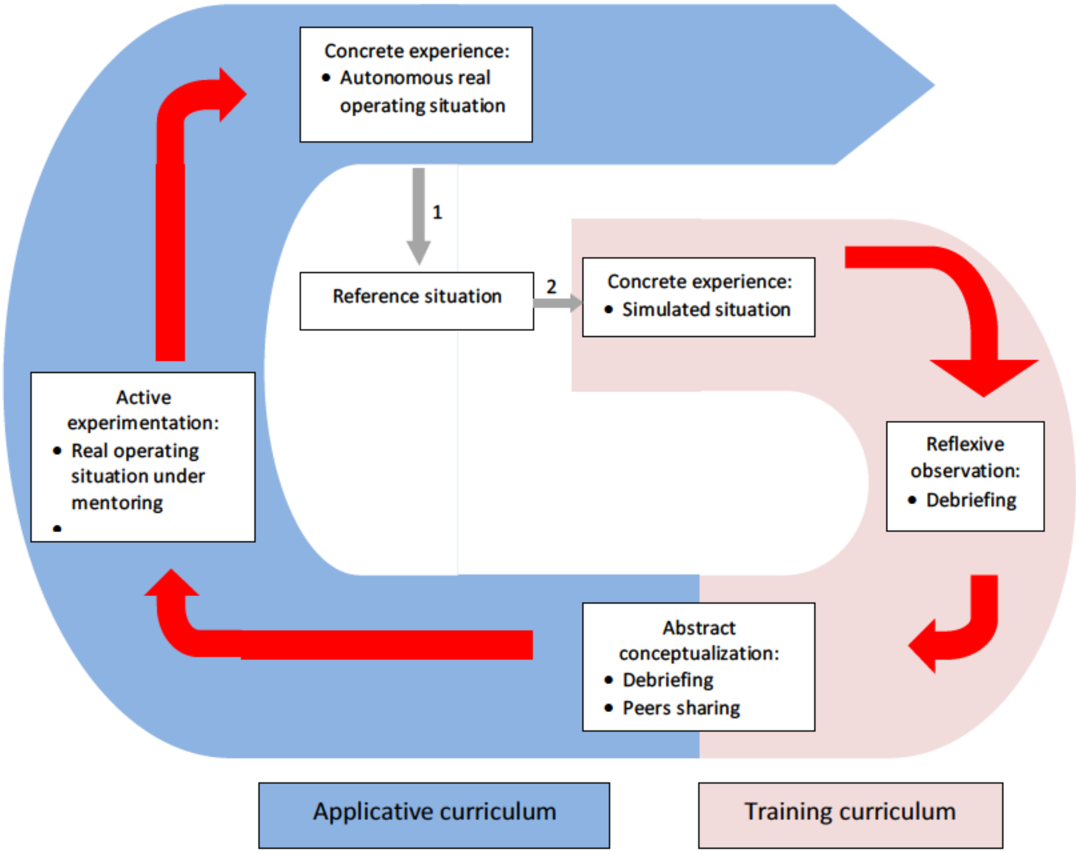


Figure 65: The excursive experiential learning cycle model. Arrow #1: the reference situation is experienced-based. Arrow #2: didactic transposition.

Another promising perspective was highlighted through the design of the "Application of RP" training sessions: in SimS, the subcam was used to obtain a subfilm of the trainees' SimS activity in order to use it as a basis for the collective 7S2P debriefing. Therefore, for this field experiment, SEBE was used through the SPEAC protocol to analyze the activity in ROS before training, and then SEBE was used in SimS during training to support training. This goes towards demonstrating that SEBE may be used as an apprenticeship accelerator under certain conditions and suggests further experiments to characterize this aspect of performance.

One of the possible limits of the SEBE/SPEAC protocol, is that it might be restrictive if used without considering the interaction of the analysed activity with the other constituents of the socio-technical system in which it is carried out. "Restrictive" means that the analysis might be exclusively or excessively focused on the subject due to the subject-oriented nature of the protocol: questions are asked using "you" and the collected data is subjective. Despite the exogenous character of some of the poles of the SPEAC model, when answering the questions, the subject might focus on particular aspect of the pole.

For example, *Being able to act* relates to means and to the help that other professions might provide; in case of problems occurring with tools whilst carrying out the activity, the subject might omit to talk about the needs of other professions. A way of addressing this limitation is to guarantee a macro approach of the analysis by forcing the analyst to consider the subject as an interactional entity within an organizational system; the aim is to be sure to question and thus include interactions for example with other professions, equipment and tools related to the subjects' activity. To do so, the set of indirect questions (see appendix 26) used to question the poles must be carefully elaborated.

Another limit relies in the presence of the recording device that might change the behaviour of recording and recorded individuals. However, subjects confessed that they were disturbed at the beginning of their activity and intended to show their best because of the recording device. They added that they very soon forgot about the subcam when involved in the nitty-gritty of the activity. In addition, should they have forced themselves to try to do their best, the bias would probably be negligible when related to the objective of the study: accessing what makes competencies of workers; the best way to obtain exhaustive results is to observe an experienced worker doing their best. Therefore, the bias induced by the first-perspective video is difficult to assess as it combines positive and negative contributions.

The field experiments for application that worked or fell through in the present research might be enriched with other cases from the literature and/or from further applications of the SEBE/SPEAC method in the aim to understand better how to define the system within which training must be considered for successful outcomes in real operating situations and how the system components must be analyzed. Results obtained in the present research already provided clues for exploration: especially the difference between field experiments for application that worked or fell through questions the configuration of the interactions between actors (trainees, trainers, workers and managers), objects (simulators, industrial equipment and tools including procedures), methods (for training: accessing what makes competencies, elaborating competencies and assessing performance) and organizations (Operations departments, Training Centers, Research teams, Support entities, companies and governments).
This refers to a multilayer-configuration distinguishing subjects (actors, implicit methods and informal organizations), physical world (objects, their utility in the organization and their affordance for subjects) and social dimension (organizations, society). Installation Theory might be of great help for such a perspective within a systemic approach since it has been elaborated as an evolutionary framework that considers a complex system according to three strata (physical, psychological and institutional) which combine and guide subjects into their activity track (Lahlou, 2008, 2009, 2017).

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NB: All web links were accessed in 2016.

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APPENDICES

Appendix 1 : ICC criteria test of the SEBE/SPEAC-based method

Tables A, B and C: Criteria test of the SEBE/SPEAC-based method (writings in bold case concern individual activity study, additional writings complete for collaborative activity study) said ICC criteria: Implementation, Capture and Conclusion.

A-Preparation phase criteria	Yes/No	Improvements
A01-Identification of the activity occurrence and of the situation is possible without any difficulty		
A02-Negotiation with the management to carry out the investigation is possible without any difficulty		

B-Capture phase criteria	Yes/No	Improvements
B01-Risk analysis researchers/managers is possible without any difficulty		
B02-Installation of external and subjective video devices / framing (less than 10 min.) are possible without any difficulty in time		
B03-Capture (subcam and camcorder) of the raw activity (from 15 min. to several hours) is possible without any difficulty		
B04-Storage of material and immediate short feedback / making appointments for the replay interview (less than 10 min.) are possible without any difficulty in time		

(…/…)

C-Analysis & Conclusion phase criteria	Yes/No	Improvements
Pre-viewing of recordings without participants and selection of particular sequences **C01-is possible without any difficulty** **C02-is not disputed by the participants during replay interview**		
C03-Replay interview: Informing participants and obtaining informed consent is possible without any difficulty		
Replay interview with one actor: two first poles of SPEAC model questioning **C04-seems correctly understood by the actor-participant** **C05-gives relevant data according to the researcher's expectation**		
Replay interview with one actor: subjective replay interview **C06-causes actor's spontaneous participation** **C07-gives relevant data according to the researcher's expectation**		
Replay interview with one actor: two last poles of SPEAC model questioning **C08-seems correctly understood by the actor-participant** **C09-gives relevant data according to the researcher's expectation**		
Replay interview with both actors: two first poles of SPEAC model questioning C10-seems correctly understood by the actors-participants C11-gives relevant data according to the researcher's expectation		
Replay interview with both actors: subjective replay interview C12-causes actors' spontaneous participation C13-gives relevant data according to the researcher's expectation		
Replay interview with both actors: two last poles of SPEAC model questioning C14-seems correctly understood by the actors-participants C15-gives relevant data according to the researcher's expectation		
C16-Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection		
Subjects' feelings including the disturbance are discussed in **C17-individual interview** **C18**-collective interview		
Subjects' goals and sub-goals are discussed in **C19-individual interview** **C20**-collective interview		
Subjects' conscious mental representations of the expected results are discussed in **C21-individual interview** C22-collective interview		
C23-Representation of collaborative activity is discussed in collective interview		
C24-The activity structure is discussed at an individual level and collective level		
Factors of coordination are discussed in **C25-individual interview** C26-collective interview		
Subjects' interactions are discussed in **C27-individual interview** **C28**-collective interview		
Subjects' conscious mental representations of tools are discussed in **C29-individual interview** C30-collective interview		
Post-analysis allows the researcher to analyze/identify C31-subjects' perspective-taking **C32-the studied system distribution** C33-the individual representation of collaborative activity and the consequences for the collective subject C34-subjects' perspective-taking and consequences **C35-the mapping out of the shared knowledge and associated communication vectors** **C36-sets of competencies required for each actor and related explicit and tacit knowledge (individual and collective aspects)**		
C37-Validation (about one hour) is possible without any difficulty in time		
C38-Validation allows researcher and actors to share findings		
C39-Validation helps the researcher to validate/adjust the conclusions		
C40-Validation gives the actors a useful feedback		

Appendix 2 : Sample of informed consent

Reference study / Reference subject	ROS-COLL-OP-AGT 08/ ....
Reference doc :	**ROS lign Cond informed consent (Eng) 01**

ACTIVITY ANALYSIS « OPERATING CIRCUIT CONFIGURATION » TO ACCESS COMPETENCIES OF PERFORMERS

Informed consent

A-1 Purpose:

Access to what makes the performers' competencies when performing operating circuit configurations in order to improve the relevance of the specifications of the associated training.

A-2 Participant profile:

Personnel involved in French nuclear power plants.

A-3 Procedure:

After carrying out specific risk analysis regarding the equipment used for the analysis of work activity, the worker in charge of the activity (eg, field worker, operating pilot) is equipped with miniaturized video recording device. Sometimes, the work analyst may also be equipped with a miniature video recording device or may use a camcorder mounted on a tripod.

Work activity is recorded at the earliest.

What is recorded is then debriefed by the analyst only with participants during an interview in order to understand what was done and how. A possible additional information may be asked to colleagues who contributed to the activity.

An analysis follows the results of which are submitted to participants for validation.

A-4 Time commitment:

The total time required to complete the study should be the time of the activity.

A-5 Recordings

Recordings are made by subcam (miniature camera mounted on glasses) or camcorder on tripod when performing the activity. The following debriefings are also recorded for later analysis for understanding and identifying what makes the competencies of the worker. These recordings and associated data are classified confidential by the analyst and are stored and used by him according to the code of ethics of his profession.

A-6 Benefits/Risks to Participant:

The workers can identify areas for improvement in their professional practices and thus enhance their skills.

All participants contribute to the improvement of the training program in general.

The only known risk for participants in this study is the misuse of data acquired. To reduce this risk, the recordings and associated data are classified confidential by the analyst and are stored and used by him according to the code of ethics of his profession.

The use of individual data is then integrated into a overall approach that does not identify the participants.

Voluntary Nature of the Study/Confidentiality:
Participation in this study is entirely voluntary; participants may refuse to complete the study at any point during the experiment, or refuse to answer any questions with which they are uncomfortable. They may also stop at any time and ask the researcher any questions they may have. Their name will never be connected to their results or to their responses on the questionnaires; instead, a number will be used for identification purposes. Information that would make it possible to identify participants will never be included in any sort of report.

Cost, reimbursement, and compensation:
Participation in this study is voluntary. There will be no supplementary income.

Questions and contacts:
During the study and after, participants may ask any questions they may have about the study. If participants have questions later, they can contact:

Dr. Fauquet-Alekhine, Work Psychologist
Email: p.fauquet-alekhine@lse.ac.uk or philippe.fauquet-alekhine@edf.fr
Address: CNPE of Chinon-BP80-F37420 Avoine
Phone: +33247987804

A-10 Declaration of consent:
The information above are read and approved.

Participant Name (*):	Name of analyst:
___________________	___________________
Date / Signature:	Date / Signature:

Thanks for participating

(*)Participants who wish to maintain some anonymity can use their initials (in agreement with the British Psychological Society Guidelines for Minimal Standards of Ethical Approval in Psychological Research).

Appendix 3 : Perception questionnaire "RGL 4 research questionnaire" regarding the training session for the periodical test EP RGL 4

20-I have already participated in the realization of EP RGL 4
21-The recall of the GRE and DMA regulations is unnecessary.
22-The recall of the GRE and DMA regulations must be done before the run onto simulator.
23-The recall of the GRE and DMA regulations must be done after the run onto the simulator.
24-I would like to pass on at least two scenarios.
25-Passing on a single scenario is enough.
26-It is necessary to pass on at least one scenario which allows to reach the 48% of power.
27-It is necessary to pass on at least one scenario which leads to the end of the test before reaching the 48% of power for a pedagogical purpose (for example: to know to stop the test).
29-The MO proposed for the simulated test is representative of the documents that I carry in the control room (similar presentation, similar number of pages, weight of the similar documentation) as to perform a real operational EP.
30-The phase of the test which consists in measuring the high point of the G3 curve must be played in the scenario.
31-Complements about the requirements regarding the test must be provided.
32-The debriefing phase following the run onto the simulator is useless.
33-The debriefing phase following the run onto the simulator lasts 2 hours and that is enough.
34-The debriefing phase following the run onto the simulator should last 3 hours to allow to train more points.
35-The data analysis phase must be integrated into training, at least the beginning of this phase.
36-The notions of the presence of on/off regulation specialists and their contribution to the test have been adequately addressed.
37-The need for the presence of on/off regulation specialists for the test must be clearly explained.
38-The different professions that should be involved to fix various technical problems must be presented.

The following questions address technical points:
21-22-23-26-27-29-30-31-35-36-37-38

The other questions address pedagogical aspects.

All questions were answered on a Likert scale except question #20:
□ Strongly disagree □ Disagree □ Neither agree nor disagree □ Agree □ Strongly agree

Appendix 4 : Example of activity description applying the SPEAC model

Job: Safety Expert (SE)
Activity: daily safety assessment
Description of the activity: the SE must assess every day the nuclear safety level of each unit of the plant. For this aim, the SE checks at random different parameters in the control room and watches the state of chosen pieces of equipment in the field and compares the results with the prescribed requirements. If any difference is observed, the SE must report to the operating team and to the management, make sure that everything is done to come back to the expected state according to the rules, and if needed ask for a declaration of a safety event.

SPEAC description:

Having to act (positive approach)	**Having to act (negative approach)**	**Dynamic relationship in the model**	**Comments**
Apply the prescription according to prescriptive documents for nuclear safety (DI122, Arrêté INB, STE, organizational notes). Satisfy the management' expectations. Check the safety parameters per unit and compare with STE. In case of differences actual/expected, ask explanation and provide analysis. In case of deviation from expectation, request actions and ask for formal notification. The prescription requires a daily meeting with operating head manager in order to exchange about the SE's assessment.	Not make sure the prescription is applied. Do not detect deviations from the prescription. Develop friendly relationship with operating team members that would distort his assessment due to unconscious willingness not to disturb friends.	The organization makes it possible (see Being able to act).	The fact that this issue was expressed both in the positive and negative terms showed its importance according to the subjects' own words.

Knowing to act (positive approach)	Knowing to act (negative approach)	Dynamic relationship in the model	Comments
Most of the knowledge is acquired during the 1.5 y training and through companionship during the same period; this is then validation by the manager who delivers “habilitation” (=certification). Following this period, the SE knows where to read the elements of prescription that must be applied. The SE knows where to find information about prescriptions. The SE knows the location of main pieces of equipement.	The SE does not memorize all prescriptions.		

Being able to act (positive approach)	Being able to act (negative approach)	Dynamic relationship in the model	Comments
The SE has access to all parts of the unit. The SE has access to all documents needed. The organization provides a daily collective meeting with peers in order to exchange about the SE’s assessment. The organization provides a daily meeting with operating head manager in order to exchange about the SE’s assessment.		The prescription makes it mandatory (see Having to act).	

Wanting to act (positive approach)	Wanting to act (negative approach)	Dynamic relationship in the model	Comments
The SE wants to do what he has to do. The SE wants to apply a shared and reliable prescription in order to guaranty nuclear safety.	The SE wants to avoid not detecting a safety deviance. The SE does not want to apply prescription that would make trades work in bad conditions.	This is expressed according to Having to act. The SE has to make the prescription being respected and applied (Having to act). If the SE feels the prescription should put workers in bad conditions to perform the task and thus makes it difficult for the SE to ask for compliance (not Wanting to act) then a interpolar conflict arise (Having to act VS Wanting to act) which may results in "ethic suffering" for the SE.	Having to act gives the motives, and the link between with the pole Wanting to act gives here elements of motivation.

Job: Operating Field Worker (FW)
Activity: locate in the field a piece of equipment
Description of the activity: the FW must handle equipment daily in an industrial field which covers several tens of thousands of square meters. Any of his actions begins by locating the piece of equipment on which he must act. To be efficient (reducing the time of the action), the FW usually knows where is this equipment or at least in which part of the unit he might find it in order to locate it fast.

SPEAC description:

Having to act (positive approach)	**Having to act (negative approach)**	**Dynamic relationship in the model**	**Comments**
This activity is mandatory for any tasks of the Operating Field Worker: no action possible on the industrial process in the field without being in front of the piece of equipment. This is expected from any FW as a constituent of the professional fundamentals.			According to the subject, the prescription or the expectation is "implicit or trivial"

Knowing to act (positive approach)	**Knowing to act (negative approach)**	**Dynamic relationship in the model**	**Comments**
All the related knowledge is acquired in the field through companionship: it is knowing the premises, knowing the nomenclature for labelling equipment, recognizing the equipment inside and knowing what it is for. However this implies knowing before "what is for what" [what the equipment has been done for], knowledge acquired in classrooms at the beginning of the professional curriculum. This helps to know how to: -recognize an functional tag -know to read/interpret a functional tag -read a mechanical drawing, a very important means to locate a priori the equipment	It is difficult to know everything: this lack of knowledge necessitates looking for equipment in the field sometimes or calling a colleague for help.	Knowing the rules of mechanical diagram for efficient reading is necessary to use this means described in Being able to act.	

Being able to act (positive approach)	Being able to act (negative approach)	Dynamic relationship in the model	Comments
Mechanical diagrams are available for help. Colleagues (and especially experienced peers) are available for help. A good physical condition is needed.	 If hurt somewhere (a leg, an arm) it may be difficult to do the job.	Mechanical diagrams can be used provided that knowledge is acquired to know how to read them.	

Wanting to act (positive approach)	Wanting to act (negative approach)	Dynamic relationship in the model	Comments
Finding the piece of equipment fast and by oneself, alone, without help: “this is a mark of competencies”.	When you ask for help every 5 minutes “you come across as an idiot”.		

Job: Operating reactor pilot (Op)
Activity: block watch-around in the control room
Description of the activity: it is common to any pilots' work: in French "le tour de bloc" which may be translated as "block watch-around". This consists in watching and checking operating parameters in the control room (see Fauquet-Alekhine & Daviet, 2015).

SPEAC description:

Having to act (positive approach)	**Having to act (negative approach)**	**Dynamic relationship in the model**	**Comments**
The block watch-around is mandatory as a part of the core missions dedicated to the operating nuclear reactor.	Better not miss a parameter out of specifications to avoid any further industrial and administrative problems.	This is directly linked with Wanting to act.	

Knowing to act (positive approach)	**Knowing to act (negative approach)**	**Dynamic relationship in the model**	**Comments**
The pilot must know what the required technical specifications are (from a prescription book called "Specifications Techniques d'Exploitation", Operating Technical Specifications). The pilot must know the physical process of the reactor and associated facilities through training in classroom, companionship and experience. It is necessary to know which physical parameters must be checked and the equipment related to these parameters (training in classroom, companionship and experience). Know how to read information from the panels, the computers. Know what must not be touch. Know the causes of alarms.			

Being able to act (positive approach)	Being able to act (negative approach)	Dynamic relationship in the model	Comments
Colleagues and especially operating team managers are here to help understanding and reminding specifications to be respected (prescription book called "Specifications Techniques d'Exploitation", Operating Technical Specifications). The book regarding Operating Technical Specifications is available in the control room and computers. Any updates of this book is available in the control room and computers.			

Wanting to act (positive approach)	Wanting to act (negative approach)	Dynamic relationship in the model	Comments
The pilot wants to ensure the conformity of the parameters with specifications (prescription book called "Specifications Techniques d'Exploitation", Operating Technical Specifications).	The pilot does not want to "be out of specifications". The pilot does not want to touch something while forbidden. The pilot does not want to miss the appropriate treatment following a problem (e.g. not applying the requested treatment in time following the occurrence of an alarm).	This is directly linked with Having to act.	The fact that it is expressed both in positive and negative forms of the pole shows that it is a main concern for the pilot.

Appendix 5 : Description of activities for the experimental test segment of the SEBE/SPEAC protocol in simulated situations (SimS).

The individual activity of valves technicians in SimS (TEST-IND-ROB-C1)

The picture of the valve is shown on Fig. 28. The neutral point set up consists in adjusting the movement of the mobile pieces of the device to electrical input signal with reference to a given position. During the activity, the intervener has several manipulations of the device to do, several position measurements to perform, calculations to do and must find the matching of some device parts. The subjective movie watched in replay interview was a 10 min. video and covered the whole activity.

Reference: Rob 2013 09\activity, fichier 445 Mo

Fig. 28: Mock-up facility of a SEREG valve used for assessment of the SPEAC model-based method during valve technician's activity. The valve's height from the bottom to the top visible on the picture is about 50 cm. The picture is extracted from the subjective video of the valve technician.

Reference video : Rob 092013\activity fichier 444Mo

The individual activity of valves technicians in SimS (TEST-IND-ROB-C2)

The picture of the valve is shown on Fig. 31. Setting cams consists in adjusting position of pieces located in the upper box of the device. During the activity, the intervener has several manipulations of the device to do, several position measurements to perform and must find the matching of some device parts.

The subjective movie watched in replay interview was a 10 min. video and covered the whole activity.

Reference: Rob 2013 12\activity, fichier 545 Mo

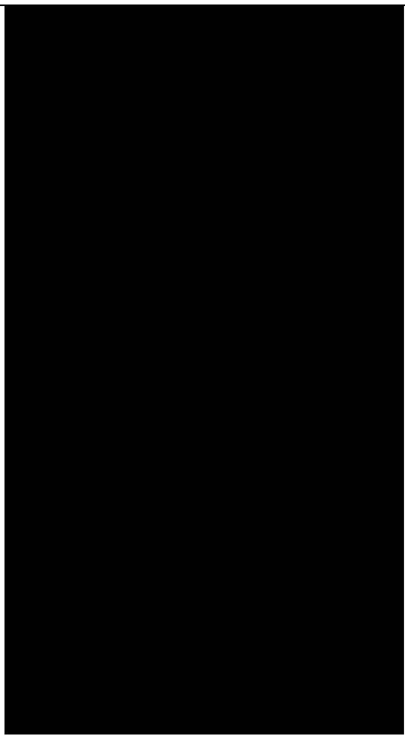


Fig. 31: Mock-up facility of a valve with cams setting used for assessment of the SPEAC model-based method during valve technician's activity. The valve's height from the bottom to the top visible on the picture is about 100 cm.
Reference pic : Rob 201312\pics\DSCN4423.JPG

The individual activity of reactor pilot in SimS (TEST-IND-OP-C0)

Fig. 32 a & b show resp. the pilot performing a block watch-around in the simulated control room and his subjective view of a control panel. During the activity, the pilot had to check the values of operating parameters on control panels.

The subjective movie watched in replay interview was a 4 min. video of the block-watch around. This time was scheduled by the negotiation done with the subject and his management: in order not to disturb the collective work in the team during the shift, it was said that the meeting would not last more than one hour, knowing that this would be enough to comment several minutes of the activity and assuming that several minutes would be enough to obtain a description of the activity that would make discovering most of the necessary related knowledge.

Reference: 20130606 part1 (OpJ), fichier 1 Go, deltat= 6 :36 -> 10 :40

Fig. 32a: Pilot performing a block watch-around in the simulated control room. Picture extracted from one of the four external video cameras implemented inside the simulator.
Reference: simu_pil_MS1_&_MSI-062013\Cam1_Simu_MSI_J2_201306_(10h57-11h26)P3110008.AVI t=04:34

Fig. 32b: Pilot's subjective view of a control panel whilst performing a block watch-around in the simulated control room.
Reference: simu pil MS1 & MSI-062013\20130606 part1 (Op J)\ fichier 1Go t=06:37

The individual activity of field worker in SimS (TEST-IND-AGT-C0)

Fig. 34 a & b show pictures extracted from the field worker's subjective view whilst performing isolation of steam generator #1 due to high level of radioactivity inside. During the activity, the field worker had to find the parts of equipment and apply the associated lines of the modus operandi.

The subjective movie watched in replay interview was a 11 min. video of the activity, beginning when receiving the request of the task by phone in the technicians' room and ending when locating the first valve of the modus operandi. This time was scheduled by the negotiation done with the subject and his management: in order not to disturb the collective work in the team during the shift, it was said that the meeting would not last more than one hour, knowing that this would be enough to comment several minutes of the activity and assuming that several minutes would be enough to obtain a description of the activity that would enable discovering most of the necessary related knowledge.
Reference: 20130604 MSI (AgTFr)\ fichier 1 Go (t=00:00 to 11:00)

t=04:01 b

t=09:34

Fig. 34 a & b: Field worker performing isolation of steam generator #1 due to high level of radioactivity inside. Picture extracted from one of the subjective videos; in a) crossing a electric cells room, b) reading the MO and wondering whether or not he must descend the caged ladder in front of him.
Reference: simu pil MS1 & MSI-062013\20130604 MSI (AgT Fr) fichiers Go et 700Mo

The collective activity of the pilot and the field worker in SimS (TEST-COLL-OP-AGT-01 & 02)

The experiment involved subjects (a pilot and a field worker) in performing collaboratively a main activity “REA configuration” lasting about 60min. and a nested activity “local checking of another part of the circuit” associated with an assumption of leak on REA circuit (REA leak) lasting about 5min. description of the activities is given below.
Situations were experienced on piloting and field simulators during a scenario that summoned a piloting team (1 manager, 1 supervisor, 2 pilots), 1 safety engineer and 1 field worker. Other necessary positions were played by the trainers.
Main and nested activities were integrated in the scenario so that they could be experienced by trainees as part of an ordinary operating day of the reactor. The overall activity goal for the Operations team was to couple the turbine of the simulated unit with the electric national network.

The main activity “REA configuration” was scheduled as follows:

- The OCL (Operator in Charge of Lockout played by a trainer) comes to see the field worker in the control room and explains to him the configuration to be done.
- The field worker prepares the task alone in the control room.
- The field worker goes and sees the pilot in the control room and explains to him what he plans to do in controlled zone, asks co-analysis and agreement.
- The field worker goes in controlled zone and here he calls the pilot for help on the phone if needed.

For this activity, the circuit followed by the demand was:

OCL->field worker->pilot

The nested activity “local checking of another part of the circuit” was scheduled as follows:

- The OCL comes to see the pilot in the control room and explains to him the problem of leak.
- The pilot and the OCL analyze the problem together in the control room.
- The pilot calls the field worker by phone, explains the problem and asks a local check.
- The field worker in controlled zone checks and calls the pilot for feedback.

For this activity, the circuit followed by the demand was:

OCL-> pilot -> field worker

Fig. 37 a to d show pictures extracted from the third-person video and the field worker’s subjective view whilst performing activity “REA configuration”. The main goal of the activity is to set up pieces of equipment related to the basic system named “REA” according to the modus operandi (MO) to allow the one-way valve 5REA545VL operating after works of maintenance. For this task “REA configuration”, the field worker had first to prepare his activity and discuss it with the pilot in the control room. Then he had to move to the “controlled zone” (radioactive part of installation) and had to find the pieces of equipment and apply the associated lines of the MO.
Reference: simu MS(I) 2013 12\MSI 2013 12 J5 IR\MSI 2013 12 IR SLB-Op1\DSCN4414.AVI (t=07:58)
Reference of external videos for the field worker: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 ZC
Reference of subjective videos for the field worker: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 AgT R

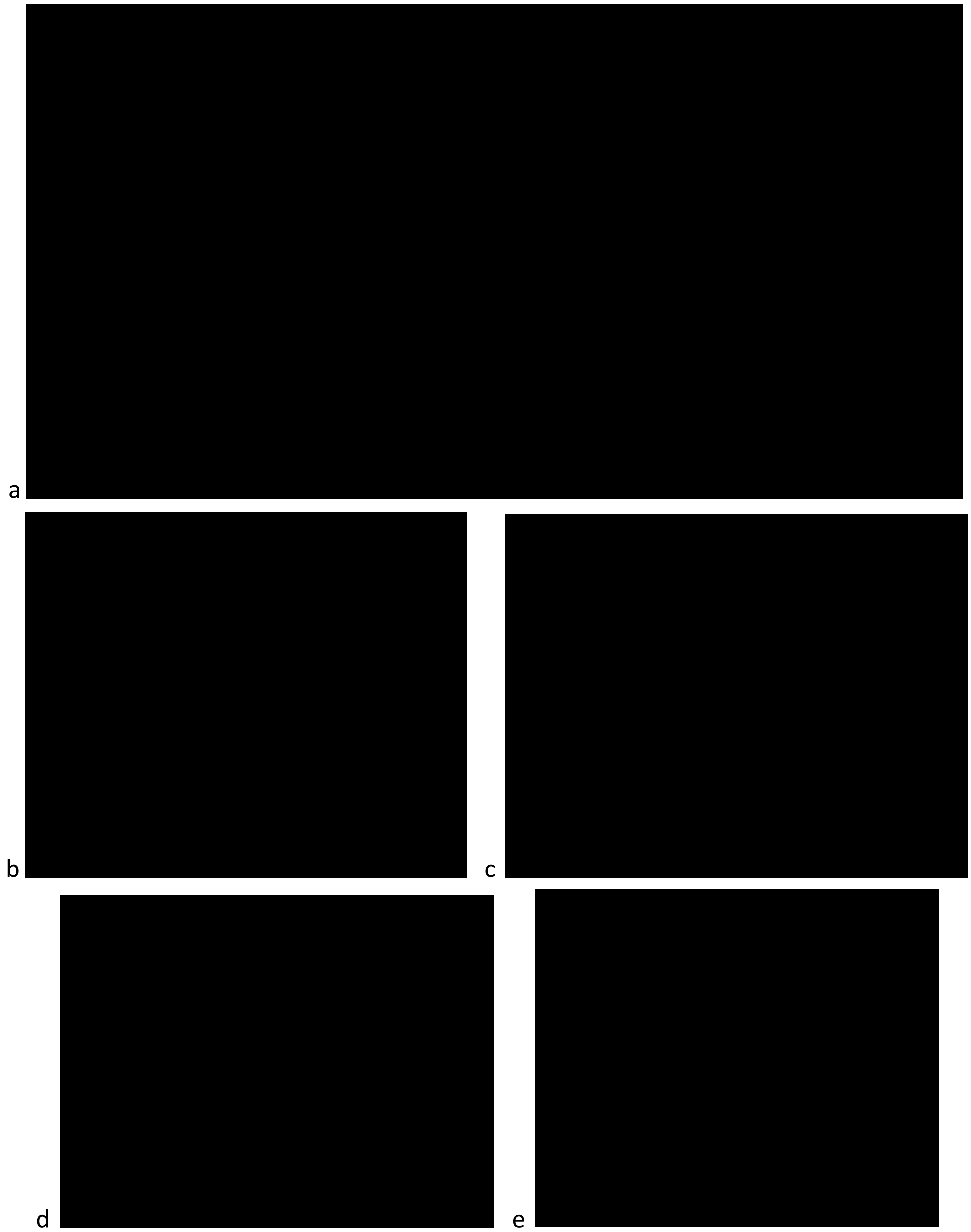


Fig. 37 a to d: Field worker's activity - Excerpts from external video record (a: exchanging with the pilot; b: checking equipment and MO in controlled zone; c: exchanging with the pilot by phone) and from the pilot's subjective view whilst performing "REA configuration activity" (d: exchanging with the pilot in the control room; e: in the controlled zone, inserting a key into a lock, valve wheel and lock in left hand, key and pencil in right hand).

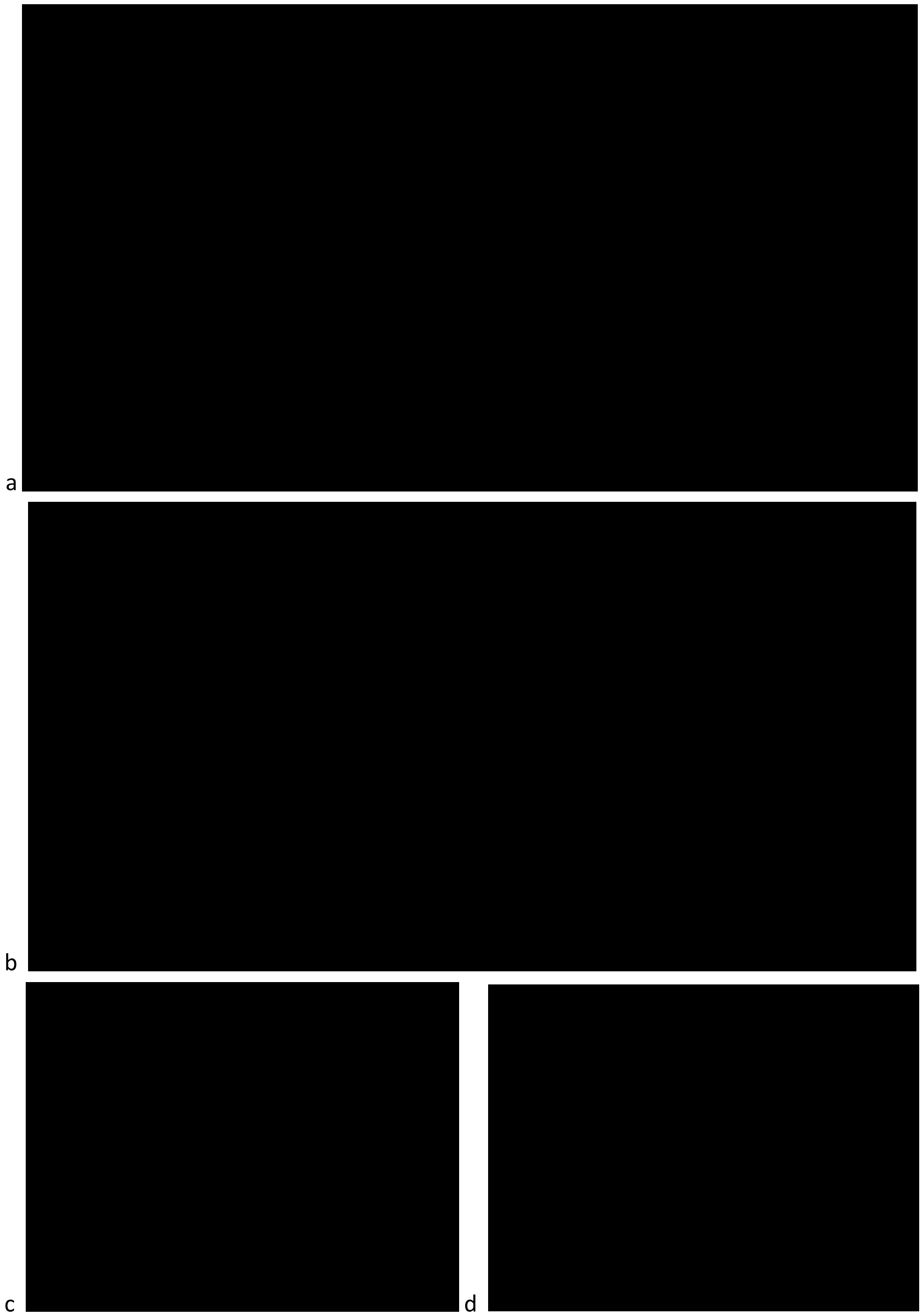


Fig. 39 a to d: Pilot’s activity - Excerpts from external video record (a: exchanging with other pilots in the control room; b: exchanging with the field worker in the control room) and from the pilot’s subjective view whilst performing activities in the control room (c: exchanging with the field worker, d: acting on a control panel).

Fig. 39 a to d show pictures extracted from external video recording and from the pilot’s subjective view whilst performing activities in the control room. During the task “REA configuration”, the pilot had to exchange with the field worker to prepare the task, then remain at the disposal of the field worker in case of need, and wait for the feedback of the field worker following the achievement of the task. Meanwhile, the pilot had to deal in the control room with other tasks to be performed in parallel of the task “REA configuration”.

Reference of external videos for the pilot: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 SdC

Reference of subjective videos for the pilot: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 Op1

The nested activity “local checking of another part of the circuit” was initiated by the detection through a flow meter indicator in the control room of a leak on REA circuit (REA leak). The Operator in

Charge of Lockout (OCL) played by one of the trainer came to meet the pilot while the main activity "REA configuration" was in progress. The OCL discussed with the pilot (Fig. 40) of the possible source of the leak and they concluded that the pilot would call the field worker to perform a local check of the pressure meter 5REA502SP.

Fig. 40: Excerpt of the pilot's subjective video whilst discussing with OCL (hand on the right), analyzing together the MO (left) and the mechanical drawing (right) to make assumptions about the leak source. They decide to check the pressure meter 5REA502SP.
Reference: simu MS(I) 2013 12\MSI 2013 12 J4\MSI 2013 12 J4 Op1\FNND0873_20131205114329.AVI (t=17:49)

The scenario had been carefully elaborated with the help of trainers of the nuclear training center of Chinon, based on external observations of work activities on nuclear power plant, on the operational feedback of the trainers, on the past experience of the trainer as pilot and on the analysis feedback of the operations work activities of the PhD researcher. "Carefully" means that several discussions between trainer and PhD researcher, then tests and adjustments aimed at ensuring that the scenario would actually include collaborative activities with a highest degree of quality made possible by the HF full scale simulator regarding operative dimension. The scenario was designed for a 3 hours run on simulator and 6 member team (two pilots, two managers, one field worker, and one nuclear safety expert), so that one of the pilot would be involved in the team work inside the control room and in two kinds of collaborative activities with one field worker as it can be observed in real operating situations. These considerations led to nested collaborative activities.
During the 3 hours run, the pilot was involved in the reactor operating and had to deal with a collaborative work with the field worker: the field worker had to be in the control room to know what was expected in the field and to prepare the work, then to exchange with the pilot during a briefing making them aware of what would have to be done. Then the field worker had to move on the field simulator to perform the configuration of the hydraulic circuit (first collaborative activity). During this time, a problem in the control room had to make the pilot to call by phone the field worker and ask him to go and check the position of a piece of equipment and call back for report (second collaborative activity). Then the field worker has to come back to the control room for final report. Both of them were equipped with subcam.
During this time, external video recordings were done in the control room, and in the field for some part of the worker's job.
External observation was done by the two researchers, one per actor (for the pilot and for the field worker). This was done to reduce the time of video analysis prior to replay interviews: doing so, sequences of the collaborative activities were identified at once.

Appendix 6 : Competencies perceived by workers when describing a chosen activity through statement S1 and questions Q1 to Q3.

S1 In your opinion, you are skilled in this activity (Likert scale (coded from -2 to +2))
Q1 In your opinion, what is firstly required in terms of competencies for a novice who will perform this activity?
Q2 In your opinion, when performing this activity, do repetition or frequency most improve your skills?
Q3: In your opinion, what makes you put your competencies in action for this activity and makes you perform it successfully?

Subject & activity						Competencies perception					Le Borterf's model					
reference	gender	age (y)	experience (y)	profession	activity	P1	Q1	Q1 verb	Q1	Q2	Knowing to act	Being able to act	Wanting to act	Additional details	Characterization of additional details	
MOD12-001	0													requested by prescriptive		
MOD12-002	0															
MOD12-003	1															
MOD12-004	1															
MOD12-005	1															
MOD12-006	1															
MOD12-007	1															
MOD12-008	1															
MOD12-009	1															on
MOD12-010	1															on
MOD12-011	1															
MOD12-012	1															
MOD12-013	1															ion
MOD12-014	1															ion
MOD12-015	1															
MOD12-016	1															ion
MOD12-017	1															
MOD12-018	0															
MOD12-019	1															
MOD12-020	1															on
MOD12-021	1															
MOD12-022	1															
MOD12-023	1															

CONFIDENTIAL

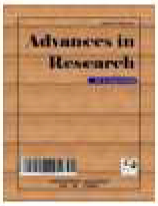
Subject & activity						Competencies perception					Le Borterf's model					
reference	gender	age (y)	experience (y)	profession	activity	P1	Q1	Q1 verb	Q1	Q2	Knowing to act	Being able to act	Wanting to act	Additional details	Characterization of additional details	
												the tag lock equipment is on				
MOD12-024	1															
MOD12-025	1															
MOD12-026	0															
MOD12-027	1															
MOD12-028	0															
MOD12-029	1															on
MOD12-030	1															
MOD12-031	1															
MOD12-032	1															erest
MOD12-033	1															on
MOD12-034	1															
MOD12-035	0															
MOD12-036	1															
MOD12-037	1															
MOD12-038	0															
MOD12-039	1															p
MOD12-040	1															
MOD12-041	1															ements

CONFIDENTIAL

Subject & activity						Competencies perception					Le Borterf's model					
reference	gender	age (y)	experience (y)	profession	activity	P1	Q1	Q1 verb	Q1	Q2	Knowing to act	Being able to act	Wanting to act	Additional details	Characterization of additional details	
															client's expectation	
MOD12-042	0															ion
MOD12-043	0															ion
MOD12-044	0															
MOD12-045	0															
MOD12-046	0															
MOD12-047	0															ements
MOD12-048	1															on
MOD12-049	1															
MOD12-050	0															

CONFIDENTIAL

Appendix 7 : Risk assessment for Subjective Evidence-Based Ethnography applied in High Risk Environment



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Risk Assessment for Subjective Evidence-Based Ethnography Applied in High Risk Environment

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Subjective Evidence-Based Ethnography (SEBE) is a family of methods developed for investigation in social science based on subjective audio-video recordings with a miniature video-camera usually worn at eye-level (eye-tracking techniques are included). Despite its application to the analysis of high risk professions (e.g. anesthetists, aircraft pilots, nuclear reactor pilots) and the potential additional risks it induces, no suggestions regarding these concerns and no solutions helping researchers to anticipate this kind of risks are available in the literature. Aiming at filling this gap, we undertook a study of SEBE equipment applied to the analysis of workers' activities on a nuclear power plant. The method was divided in three phases: i) observations and discussions on full scale simulators of activities undertaken by one or two workers (*N*=42) to characterize the consequences of the SEBE equipment, ii) bibliographic research combined with results of first phase to elaborate a risk assessment protocol, iii) analysis of its application in real operating situations (*N*=17). The elaborated protocol gave satisfactory results in terms of risk prevention and time application: No incident or accident occurred and the risk assessment took less than five minutes. The observations highlighted however a risk of side-effect (using SEBE equipment to justify subjects' mistake or

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failure) giving greater importance to the necessity of this sort of risk assessment protocol. To date, the protocol needs to be tested in other industrial contexts in order to be improved and/or to confirm its robustness.

Keywords: Activity analysis; eye tracking; high risk industry; risk assessment; miniaturized camera; video.

1. INTRODUCTION

Using video recordings allows the researcher to access to the reality of work activities which is one of the major concerns of work analysts. The use of video has almost become a necessity because it pushes the limits of the classic observation paper / pencil: Even with the help of analysis grids, the researcher's writing speed is often much slower than the performance of the task by observed workers. In addition, taking notes entails the risk of not watching the scene for a while and so to miss important elements of activity. This could be corrected by replaying the activity but in the world of work, it is generally inappropriate to ask to redo several times the activity observed while video allows for multiple visualizations retrospectively, very useful in the case of complex situations. When the work analyst applies self-confrontation, the video recording is a main tool: observed subjects seeing themselves in action can learn about themselves and thus correct or improve themselves. Thus, the video is both a source and a support: a data source for the researcher and a support of expression (body, speech), of mediation, which participates in the emergence of meaning of the activities and of the co-production of knowledge through the triangle operator-image-researcher [1].

As noticed by others, video analysis may help researchers "to reveal how activities are produced with respect to the contingencies and circumstances of the participants within organizational settings, and examine how the technologies available in these domains are utilized" [2].

Amongst all the possible devices available for such video recording of activities, the first person approach or subjective approach presents the particularity to use a recording device embedded on the subject in action. The point of view of the camera is then that of the subject: this characterizes the first person or subjective point of view. This kind of approach was conceptualized by Lahlou [3,4] under the name of Subjective Evidence-Based Ethnography (SEBE). The SEBE is thus a family of methods developed for investigation in social science based on subjective audio-video recordings with a miniature video-camera most of the time worn at eye-level (the subcam), then confrontation of subjects with these subjective recordings to collect their subjective experience, and finally discussion of findings and final interpretations between researchers and subjects. The use of a subjective perspective brought interesting series of improvements on the quality of the explanation by the subject's intentions when rendering in self-confrontation interview with the subjective videos [5].

The recent progress regarding miniaturized cameras and camcorders helps new researchers to reach a deeper layer of analysis. For example, the consumers' behavior analysis through subjective recordings avoiding disturbance due to heavy and bulky equipment was obtained [6,7]. Gobbo [8] applied the SEBE approach to shoes consumption (videos are available on line: ethnoshoes.com). Fauquet-Alekhine et al. [9] analyzed consumers' behavior shopping wines in stores for marketing concerns. Similarly, these devices allow researchers to access relevant data regarding work activity: examples of application are available for nuclear industry [10-12].

SEBE also includes eye-tracking systems (see the reviews [13,14]). Researchers have used this kind of devices to analyze and improve training [15-17], to analyze consumers' behavior [18-20], to study high risk professions such as anesthetists [21], aircraft pilots [22-24], flight fighters [25], air traffic controllers [26], nuclear reactor pilots [27].

The use of SEBE metrology equipment does not present any special risks for the subjects themselves. Conversely, SEBE equipment applied to the analysis of high risk professions might induce problems due for example to the interaction between the SEBE equipment and the work environment (cables may be trapped in the industrial equipment) or due to a disturbance of subjects' actions (SEBE glasses might change the subjects' vision). Despite these potential additional risks induced by SEBE equipment, the literature is void of suggestion regarding these concerns and of solutions helping researchers to anticipate subsequent problems.

This paper aims at providing a devoted risk assessment for SEBE application for high risk professions.

2. MATERIALS AND METHODS

2.1 Design

The high risk professions chosen to undertake this study was the professionals of nuclear industry at the nuclear power plant (NPP) of Chinon (Electricité de France). The analysis frame was bounded by the analysis of their work activity (see for example [12]).

A first phase (first observations and discussions) was undertaken on simulators to observe and discuss with workers (*N*=42) the consequences of the SEBE equipment used. Three kinds of professions were observed: Reactor pilot, operating field worker, and maintenance technician.

A second phase (risk assessment elaboration) was related to a bibliographic research regarding possible risk assessment protocol in high risk industries and to the development of the SEBE risk assessment.

A third and final phase (application) consisted in applying the elaborated risk assessment of phase 2 in real operating situations. Professions concerned were the same as for phase 1 but subjects (*N*=17) were other persons.

All studied situations involved one or two subjects at the same time in a given work activity. These situations were real operating situations therefore exposing subjects to interactions with the industrial environment in operation and to interpersonal contacts with colleagues including all constrains induced by their job and by interactions with other jobs.

2.2 Subjects

For phase 1, reactor pilots were observed and then interviewed in the simulated control room. *N*=30 subjects (age: 25 to 45 yo.; professional experience: several months to 13 years) were equipped with SEBE equipment whilst evaluating safety (individual activity) or dealing with periodical tests of the process (collective activity). Operating field workers were observed and then interviewed in the field simulator. *N*=10 subjects (age: 25 to 45 yo.; professional experience: several months to 15 years) were equipped with SEBE equipment whilst configuring hydraulic circuit (individual or collective activity). Maintenance workers were observed and then interviewed in one of the tap and valve simulators. *N*=2 subjects (age: 45 yo.; professional experience: 20 years) were equipped with SEBE equipment whilst working with valves and related actuator devices. All these activities lasted from several minutes to 2 hours. All simulators were located at the Training Center of the NPP of Chinon.

For phase 3, reactor pilots were observed and then interviewed in one of the control rooms. *N*=5 subjects (age: 25 to 45 yo.; professional experience: several months to 10 years) were equipped with SEBE equipment whilst evaluating safety (individual activity) or dealing with periodical tests of the process (collective activity). Operating field workers were observed and then interviewed in the field. *N*=10 subjects (age: 25 to 35 yo.; professional experience: 1 to 7 years) were equipped with SEBE equipment whilst configuring electric or hydraulic circuits (individual or collaborative activity). Maintenance workers were observed and then interviewed in one of the electric premises. *N*=2 subjects (age: 28 and 40 yo.; professional experience: 5 and 15 years resp.) were equipped with SEBE equipment whilst undertaking the test of a part of the control system of the installation. All these activities lasted from several minutes to 3 hours and took place at the NPP of Chinon.

As the aim was to develop a SEBE risk assessment for anyone of the staff, gender, age and experience were not considered as variables to be analyzed, yet subjects were chosen so that a large range of age and work experience could be represented by the sample.

2.3 Apparatus

All simulators were of full scale type, reproducing with a high degree of fidelity the real operating material and environment of a NPP, as well as the real kinetic of physical parameters.

The SEBE equipment was made up of three parts linked with cables: i) a micro audio digital recorder DVR-500-HD2 self powered by internal batteries, ii) a 4 mm diameter - 40 mm length miniaturized subcam mounted on safety glasses, iii) a lavaliere microphone. This SEBE equipment was purchased at Active Media Concept.

Reactor pilots were dressed with their own civil garments. Other professionals wore individual safety equipment including overalls, helmet, shoes and gloves if needed.

2.4 Procedure

Phases 1 (first observations and discussions) and 3 (application) required a prior discussion with the management of the teams (operating and training) in order to present the study, negotiate hierarchical agreement, and identify the possible subjects and activities. Then a preparation was undertaken with the subject(s) in order to explain the aim of the research, discuss of agreement and sign the ethical form. Only for phase 3, the preparation included the application of the SEBE risk assessment protocol elaborated in phase 2. After equipping the subject(s), work activity was engaged by the subjects and / researchers began making observations using pencil and paper. No particular instruction was given to subjects: They just had to perform their task as usual. Observations focused on interactions of the SEBE equipment with the environment and subjects. Immediately after the end of the time planed for the experimentation, a semi-structured interview was carried out by the researchers with the subject(s). Questions were asked regarding subjects' perception of their own safety and comfort whilst wearing SEBE equipment, their ability to act, to perform the task, constrains induced by the SEBE equipment on their activity, the interaction between the SEBE equipment and their garments or the industrial equipment. A final open question left place for additional comments. The difference between phase 1 and phase 2 lied in the final interview: for phase 1, the goal was to explore the risks, for the phase 2, the goal was to complement the protocol.

Phase 2 (risk assessment elaboration) began with a list of potential risks due to the SEBE equipment elaborated from the material obtained in phase 1, also fostered by feedback from others studies [3,11,28,29]. These risks were then categorized in order to identify families of potential risks. It was here assumed that risks of a given family could be identified by the same set of questions. In these conditions, it would make the risk assessment more concise.

In parallel, a bibliographic research was undertaken to explore the risk assessment in high risk industries. Four industries were considered: Nuclear, aerospace, airline, and medicine. The investigation focused on available approaches, methods and protocols of risk assessment of work activity in order to adapt it in the case of the SEBE use.

3. RESULTS

3.1 Results of Observations, Interviewers (Phase 1) and Additional Feedback

The first observations from the researchers as well as the first remarks from the subjects concerned the interaction of the SEBE equipment with their body and with their worn equipment: these resulted in comments (positive or negative) regarding the SEBE glasses over their own glasses, the way they had to adjust their own glasses whilst working (one of the pilot was used to pushing back his glasses on the nose (a tic) and another was used to pushing his glasses up on his front when reading certain indicators of the control panel). This led us to consider other possible interactions with prostheses (hearing aid, lenses) and to question the relevancy and the adjustment of the positioning of the SEBE equipment on the subjects.

The operating field workers were wearing overalls with a lot of pockets and a lot of things inside. These led us to question the possible interaction between these objects and SEBE equipment, especially with the cables. As a consequence, the reliability of their movements, of their actions, as well as of their speed of action was questioned. Observations pointed out possible interactions between the SEBE equipment (especially the cables) and the industrial equipment in the case of operating field worker and maintenance worker.

Finally, it appeared important to remind to the subjects that the most important was to perform their work activity and that, in case of discomfort due to the SEBE equipment, this latter had to be taken away at once.

3.2 Results of the Risk Assessment Elaboration (Phase 2)

The results of phase 1 led to a questionnaire for risk assessment divided in 5 categories addressing a specific field of the experiment for work activity:

- Usual biotechnical constraints (including concerns about individual's safety and comfort),
- Biotechnical constraints of the activity,
- Performance constraints,
- Equipment safety,
- Induced biotechnical constraints (including concerns about individual's safety and comfort).

Each category was then broken down into several questions:

1-Usual biotechnical constraints
1.1-Do you wear a hearing aid?
1.2-Do you wear lenses?
1.3-Do you wear glasses?
1.4-If Yes to any of the questions, is this resulting in particular regular manipulations?

2-Biotechnical constraints of the activity
2.1-Do you wear equipment that may interact with the SEBE equipment? (e.g. belt metrology, helmet, ear plugs, prostheses)

3-Performance constraints
3.1-Can SEBE metrology reduce the reliability of your movements?
3.2-Can SEBE metrology reduce the speed of your movements?
3.3-Can SEBE metrology mechanically interact with your work environment, causing damage? (e.g. span, crawl, slip, climb)

4-Equipment safety
4.1-Could SEBE Metrology be damaged?
4.2-Could SEBE Metrology be infected, contaminated?

5-Induced biotechnical constraints (once SEBE metrology in place). Do you feel a particular discomfort for:

5.1-The field of vision?
5.2-Listening?
5.3-The weight of the glasses?
5.4-The placement of the camcorder?
5.5-The placement of cables?
5.6-The length of the cables?

A final reminder was added: The reminder was that the priority is the work activity carried out by the workers. In case of discomfort felt by workers due to SEBE equipment, workers must request its immediate withdrawal.

The bibliographic research undertaken to explore the risk assessment in four high risk industries (§2.4) gave relevant results from nuclear and aerospace industries.

The Institute of Nuclear Power Operations (INPO) highlighted the necessity to have constant risk assessment: "Nuclear safety undergoes constant examination" is one of the 8 principles of a strong nuclear safety culture [30]. "Insights from probabilistic risk assessments are considered in daily work activities and change processes" [31] promoting constant examination. This means that risk assessment is more than one examination: the risk assessment must be undertaken every time performing the activities as the context and/or the actors are always new. For the SEBE, we applied this as the necessity to perform a systematic risk assessment before each application, even if we had the same subject and/or the same activity.

The International Atomic Energy Association (IAEA) provided a probabilistic approach of risks and promoted a method for risk assessment based on consequences and frequency (Fig. 1):

> The process of quantified risk assessment is probabilistic in nature. It recognizes that accidents are rare and that possible events and risks cannot be entirely eliminated. Because major accidents may or may not occur over the entire life of a plant or a process, it is not appropriate to base the assessment process on the consequences of accidents in isolation. The probability of this kind of accidents actually occurring should be taken into account. [32].

To operate this approach concretely, we applied the risk assessment matrix of the National Aeronautics and Space Administration (NASA) [33], in full agreement with the recommendations of IAEA, simple and quite clear. In this approach, coherent with most of those applied in high risk industries since the work of Farmer [34], gravity is evaluated in terms of consequences. The matrix approach is a cross assessment of the probability and consequences which are both rated on a five step scale:

> Very low, low, moderate, high, very high

The definition of the steps is given in the Tables 1 and 2. They are presented according to four domains: Safety, technical, cost, schedule.

For example, in Table 1, it is suggested that a given space program may be concerned by very high risks if an identified risk has a probability to occur during the program greater than 10^{-1} (safety domain) or if the probability not to meet the expected performance is greater than 50% (technical domain) or if the probability of an over cost is greater than 75%.

Regarding the safety concern, as done by Probabilistic Risk Assessment (PRA) for high risks industries, we considered probability as a frequency related to the experiment. Yet, the PRA of NASA as well as of INPO considered the probability of occurrence related to a whole space mission or a whole industrial unit operation of which scale of assessment may be several hours, weeks, months or years [32]. Regarding our experiment, we were interested in the impact of wearing the SEBE equipment. This was a permanent situation and we considered that the appropriate scale of assessment was the second. This led to the following association in Table 3.

Risks were then assessed in the 5x5 matrix according to Fig. 2.

The global aim of a risk assessment is to identify risks for the activity and then implement remedial measures to reduce risks and return all of them in the green area (bottom left corner) of the 5x5 matrix if possible.

On Fig. 2, we adopted a nomenclature to designate:

- probability: *p* (in subscript on Fig. 2)
- consequence: *c* (in subscript on Fig. 2)
- very low, low, moderate, high, very high: VL, L, M, H, VH

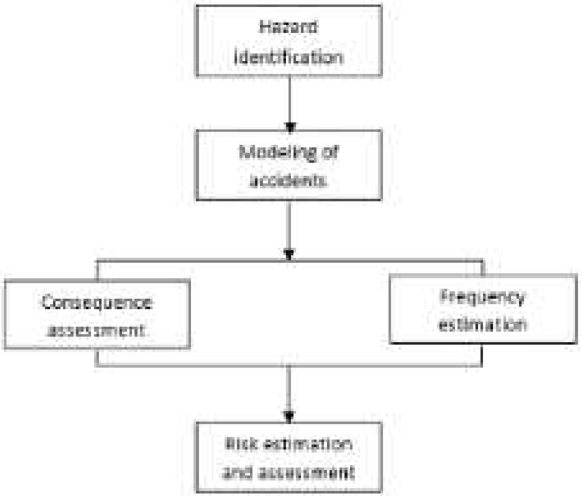

Fig. 1. Overview of quantitative risk assessment procedure. Adapted from IAEA [32]

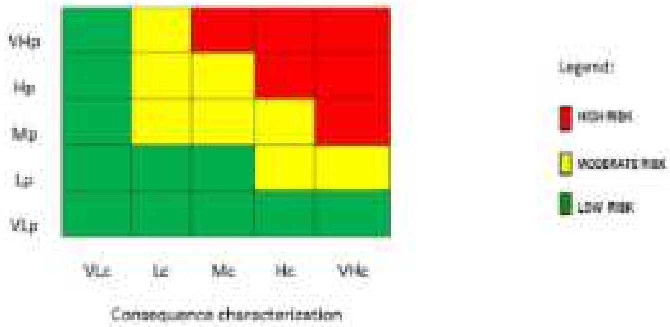

Fig. 2. Risk assessment in the 5x5 matrix Probability vs Consequence characterization

Table 1. Definition of the five steps scale for probability. Adapted from Alcom et al. [33]

Probability	Safety (estimated probability of safety event occurrence)	Technical (estimated probability of not meeting performance)	Cost/Schedule (estimated probability of not meeting cost or schedule commitment)
VH: Very High	$p_s > 10^{-1}$	$p_T > 50\%$	$p_{CS} > 75\%$
H: High	$10^{-2} < p_s \leq 10^{-1}$	$25\% < p_T \leq 50\%$	$50\% < p_{CS} \leq 75\%$
M: Moderate	$10^{-3} < p_s \leq 10^{-2}$	$15\% < p_T \leq 25\%$	$25\% < p_{CS} \leq 50\%$
L: Low	$10^{-4} < p_s \leq 10^{-3}$	$2\% < p_T \leq 15\%$	$10\% < p_{CS} \leq 25\%$
VL: Very Low	$p_s \leq 10^{-4}$	$0.1\% < p_T \leq 2\%$	$p_{CS} \leq 10\%$

Table 2. Definition of the five steps scale for consequences. Adapted from Alcom et al. [33]

Risk	VL: Very Low	L: Low	M: Moderate	H: High	VH: Very High
Safety	Negligible or No impact.	Could cause the need for only minor first aid treatment.	May cause minor injury or occupational illness or minor property damage.	May cause severe injury or occupational illness or major property damage.	May cause death or permanently disabling injury or destruction of property.
Technical	No impact to full mission success criteria.	Minor impact to full mission success criteria.	Moderate impact to full mission success criteria. Minimum mission success criteria is achievable with margin.	Major impact to full mission success criteria. Minimum mission success criteria is achievable.	Minimum mission success criteria is not achievable.
Schedule	Negligible or no schedule impact.	Minor impact to schedule milestones; accommodates within reserves; no impact to critical path.	Impact to schedule milestones; accommodates within reserves; moderate impact. to critical path.	Major impact to schedule milestones; major impact to critical path.	Cannot meet schedule and program milestones.
Cost	<2% increase over allocated and negligible impact on reserve.	Between 2% and 5% increase over allocated and can handle with reserve.	Between 5% and 7% increase over allocated and cannot handle with reserve.	Between 7% and 10% increase over allocated, and/or exceeds proper reserves.	>10% increase over allocated, and/or can't handle with reserves.

The definition of the steps is given Tables 1 and 2. They are presented according to four domains: Safety, technical, cost, schedule. Regarding the SEBE method, cost and schedule are not impacted domains provided that the SEBE equipment is not destroyed. This issue is addressed through the technical domain. Hence, the protocol we elaborated below examined points from the safety and technical standpoints only. Therefore, each question related to the five categories of risks listed in section 3.2 gave rise to an assessment according to safety and performance domain, concretely achieved through an assessment form presented in Figs. 3 and 4 as an example for question 1.1 of the SEBE risk assessment protocol.

These forms (Figs. 3 and 4) were completed at the beginning of the document by an introduction sheet explaining briefly how to apply the document and by three summarizing grids at the end of the document, each one related to the type of risks (red in upper right corner, green in bottom left corner, yellow in the middle, in the matrix Fig. 1).

Table 3. Appropriate scale of assessment for safety probability or likelihood

Probability	Frequency
10^{-1}	1/10 sec
10^{-2}	½ min
10^{-3}	1/15 min
10^{-4}	1/10 j

The introduction sheet reminds the user the color code associated to the risk level and what is an acceptable risk according to the matrix. It also presents a Table on which the designation of the activity studied and the names of the performers must be written by the analyst as well as the date of the risk assessment and the participants' names, complemented by the time and date of the activity performance and the performers' names. This information is important because it helps the analyst to prove that people performing the task were involved in the risk assessment. The Table also offers the possibility to write down the number of conclusions identified during the risk assessment. This information is relevant as it helps analysts and workers to know whether or not they have something to do to minimize the risks by a quick look in case of activity realized later than the time of the risk assessment: if the number of conclusions is "0", no significant risk was identified; otherwise the summarizing grids at the end of the document must be read. On these grids, the analyst writes the number of the questions concerned by a risk identified, for which domain (safety and/or technical) and what must be done.

3.3 Application of the SEBE Risk Assessment in Real Operating Situations (Phase 3)

The whole document obtained was thus made up of thirty-four pages (available for free on line at http://www.hayka-kultura.org/larsen.html). Using this document for SEBE risk assessment implies beginning by filling the Table on the introduction sheet. This was achieved during the preparation phase with the subject(s) just before performing the work activity. Then, turning the page, the first question 1.1 (Fig. 3) was asked to the subject(s) regarding safety domain and in case of answer "YES", consequence was identified clearly and written in the box "1" under "consequence", then characterized and probability evaluated. In case of several consequences, box "2" and "3" could be used. The pairs (characterization; probability) were then drawn on the matrix writing "1" for consequence #1 and so on. In case of ticking inside the yellow or red area, remedial had to be written in the next box. Then the next page was considered (Fig. 4), asking the same question 1.1 from the performance standpoint, and a similar analysis was carried out. This was then done for the next questions. In case of answer "NO", the page was turned without any comment.

At the end of the document, all identified consequences were summarized in the last three summarizing grids and the total number of consequences identified and reported in the grids was noted on the introduction sheet. Doing so, it was easy to consult the document later and know how many risks and remedial were identified and not forget any of them.

Application of the SEBE risk assessment document with workers in real operating situation was indeed easy and quick. Most of the answers to the questions were negative and the protocol was applied in less than five minutes.

There was a recurrent positive answer to question #3.3: "Can SEBE metrology mechanically interact with your work environment, causing damage?" for the operating field workers and maintenance workers. The systematic remedial action was to run the SEBE metrology cables inside the overalls.

There were no cases of subjects equipped with a hearing aid. No case of possible infection or contamination of the SEBE metrology equipment was encountered.

Only one case of discomfort was reported (questions of category #5) not during the risk assessment but during the interview after performing the activity. The subject was a reactor pilot.

No case led to withdrawing the SEBE metrology equipment.

No incident or accident was observed or reported.

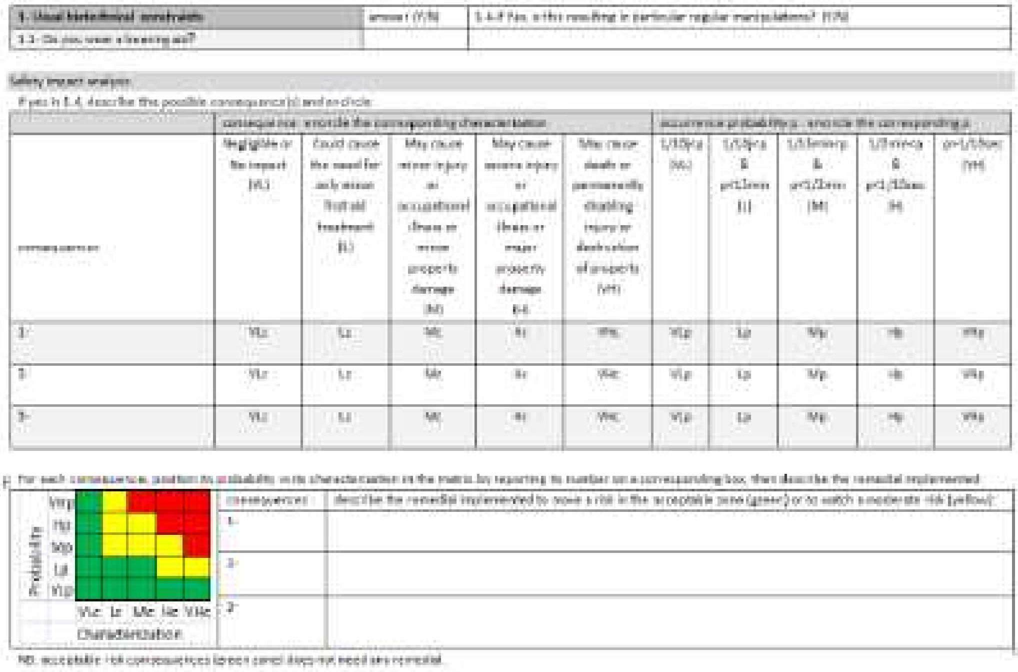

Fig. 3. SEBE risk assessment form for question 1.1 related to safety domain

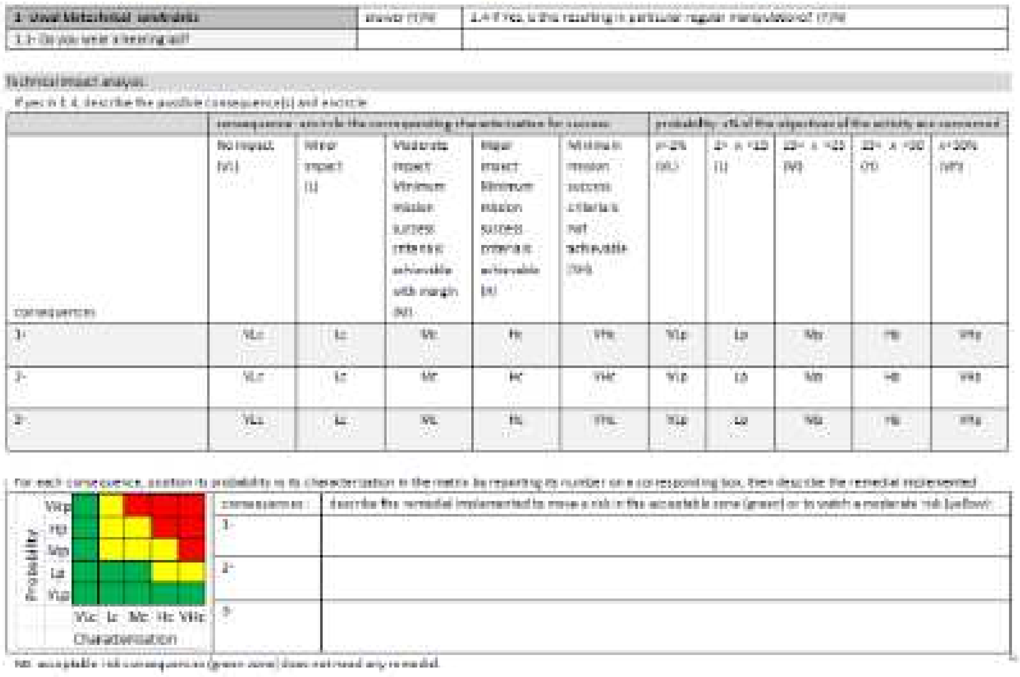

Fig. 4. SEBE risk assessment form for question 1.1 related to performance domain characterization

4. DISCUSSION

4.1 Contribution

When obtaining the SEBE risk assessment protocol after phase 2, a worry came to our mind regarding the time which would be necessary to apply it: Usually, additional tasks are never welcome in the course of industrial activities because they reduce efficiency by increasing the time of work. We were pleased to demonstrate finally that this did not take more than about 5 minutes.

The fact that no problem was encountered and just one complaint was reported by the subjects whilst applying the SEBE equipment with prior risk assessment in real operating situations is encouraging: It suggests that the developed protocol for SEBE risk assessment may be a relevant tool. Problem due to the dimensions of the device would perhaps have been different with a bigger camera, especially for field workers in narrow premises.

The complaint regarding SEBE equipment concerned just one case of discomfort reported during the interview after performing the activity (1 subject over 17 in the application phase 3). The subject was a student reactor pilot. However, observations led to the assumption that this person was using any reason to justify his difficulties in achieving the tasks (lack of competencies). Yet, due to ethical concerns, this point could not be discussed neither with his managers nor with his colleagues for confirmation or not. This highlighted a very important point: if an individual may attempt to hide a kind of lack of competencies by invoking the effect of the SEBE equipment, we may assume that, in case of accident occurring in situation, the SEBE equipment might be designated by the subjects as a main factor contributing to the accident even though it would not be really the case. This finding gives even greater importance to the necessity of this sort of risk assessment protocol. Indeed, in case of the occurrence of an accident whilst using the SEBE equipment with risk assessment beforehand, there are arguments to defend the absence of contribution of the SEBE equipment to the accident. Obviously, this does not prevent the workers to make by their side the risk analysis of their own activity.

This protocol may be applied to any kind of SEBE, including wireless devices or systems for which the camcorder and/or the microphone are integrated inside the glasses: In these cases, the related questions are merely not applicable.

4.2 Quantitative Approach

Risk assessment addressing SEBE use is quite new and therefore suffers of a lack of experience feedback on the contrary of space programs or nuclear reactors operation. A long experience feedback helps analysts to make the risk assessment more accurate by fostering probability data with the frequency of event occurrences. For example, the repetitive failure of a given sensor *m* times over a ten year space program including *M* launches of a rocket equipped with this sensor helps analysts to adjust the probability of failure of this sensor to m/M. The SEBE unfortunately does not have any benefits of this kind as it has never been considered from such a standpoint until today. Nevertheless, from the N=42 cases used to elaborate the protocol and then from the N=17 cases for application, we may conclude that the thresholds suggested by the NASA to bound the technical levels (Table 1) and that the thresholds selected to bound the safety levels (Table 3) are appropriate: indeed, applications in working situations led us to implement remedial actions that avoided any problem in the considered industrial domain. For example, while the placement of the cables was not pointed out as inducing a possible difficulty for reactor pilots, this was not the case for field workers for whom keeping the cables inside the vest was recommended.

4.3 Limits

Despite the fact that results of the present study suggest that the developed protocol for SEBE risk assessment may be a relevant tool, the application as well as the exploratory phase preceding the elaboration of the protocol concerned only one industrial field. Furthermore, no particular biotechnical constraint was met except wearing glasses: it should be interesting to deal with subjects concerned by prostheses. The same for equipment safety with infection or contamination. It would be worth to test the application of the protocol in context of other high risk industries in order to submit it to other fields of constraints and test its robustness and learn whether or not the protocol needs improvement and complements.

5. CONCLUSION

A protocol for risk assessment regarding the application of SEBE metrology equipment was validated for work activities in nuclear power plant. This protocol was based on the recommendations and applications of the International Atomic Energy Association, the Institute of Nuclear Power Operations and the National Aeronautics and Space Administration.

The protocol gave satisfactory results in terms of risk prevention and time duration application. We found important to add a reminder in the protocol document for the subjects not to forget that the priority remains the work activity carried out by them. In case of feeling any discomfort due to SEBE equipment, they must request its immediate withdrawal. Furthermore, recommend-dations of INPO (§ 3.2) led us to highlight the necessity to perform a systematic risk assessment before each application, even if we had the same subject and/or the same activity.

The observations highlighted however a risk of side-effect: Workers who are not at ease in their job due to lack of skills might say that the SEBE equipment was disturbing them to justify a problem and not to accept their own responsibilities; moreover, in case of an accident, SEBE metrology equipment could be accused as disturbing workers even though it was not the case. These findings gave greater importance to the necessity of this sort of risk assessment protocol.

This protocol may be applied to any kind of SEBE, including wireless devices or systems with integrated camcorder and/or the microphone inside the glasses. Yet, the protocol needs to be tested in other industrial contexts in order to be improved and/or to confirm its robustness. Despite that, the SEBE risk assessment protocol we obtained clearly fills a gap with efficiency for researchers and analysts using SEBE techniques.

CONSENT

The author declares that written informed consent was obtained from subjects for publication of this paper.

ETHICAL APPROVAL

This study received ethical approval of the Ethics Committee of the Dept. of Social Psychology (LSE, London, UK) and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

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COMPETING INTERESTS

The author has declared that no competing interests exist.

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Appendix 8 : Perception questionnaire for trainees regarding self-perception of the training session for "Applying Reliability Practices" at the NPP.

Questions 2 to 10 were answered by the trainees on a Likert scale:

□ Strongly disagree □ Disagree □ Neither agree nor disagree □ Agree □ Strongly agree

1-Have you been trained in Reliability Practices before today?

2-Do you think that the analysis of the subjective film is a real added value compared to a training session without a subjective film (ie a so-called "classical" method)?

3- Do you feel that you made any progress regarding the studied RP by the proposed method?

4 - Do you feel that you made any progress regarding the studied RP by the proposed method more than with a so-called "classical" method?

5- Do you consider the proposed method (miniaturized camera and analysis of the subjective film) constraining for you?

6- Do you think the proposed method is innovative?

7- Do you consider the proposed method difficult to apply by the trainers?

8- Do you think that the proposed method is worth to be applied to other kinds of training programs?

9- Do you consider that the proposed method makes it possible to highlight particularities which remain invisible with a classical method?

10- Do you think the proposed method is worth to be applied to your colleagues?

Appendix 9 : Motivation assessment questionnaire used for residents' medical training

Based on the Motivated Strategies for Learning Questionnaire (MSLQ) of Pintrich et al. (1991)

The French version used in the present research:

Les questions suivantes portent sur votre motivation et votre attitude au sujet de cette session de formation.
Il n'y a pas de bonnes ou mauvaises réponses, il faut juste répondre aussi précisément que possible. Utilisez l'échelle ci-dessous pour répondre aux questions. Si vous pensez que la déclaration est très vraie pour vous, cerclez 7; si une instruction n'est pas du tout vraie pour vous, cerclez 1. Si la déclaration est plus ou moins vraie pour vous, trouver le numéro entre 1 et 7 qui vous décrit le mieux.

	items	évaluation 1- Pas du tout vrai pour moi … 7-Tout à fait vrai pour moi						
		1	2	3	4	5	6	7
1(4)	Je pense que je vais être en mesure d'utiliser ce que j'ai appris dans cette session dans d'autres circonstances.	1	2	3	4	5	6	7
2(5)	Je crois que je vais recevoir un excellent score dans cette session.	1	2	3	4	5	6	7
3(6)	Je suis certain(e) que je peux comprendre les éléments les plus difficiles présentés dans les documents pour cette session.	1	2	3	4	5	6	7
4(7)	Obtenir un bon score dans cette session est la chose la plus satisfaisante pour moi en ce moment.	1	2	3	4	5	6	7
5(10)	Il est important pour moi d'apprendre les éléments de cours dans cette session.	1	2	3	4	5	6	7
6(11)	La chose la plus importante pour moi en ce moment est d'améliorer mon score global, donc ma principale préoccupation dans cette session est d'obtenir un bon score.	1	2	3	4	5	6	7
7(12)	Je suis confiant(e) sur le fait que je suis capable d'apprendre les notions de base enseignées dans cette session.	1	2	3	4	5	6	7
8(13)	Si je peux, je veux obtenir un meilleur score dans cette session que la plupart des autres participants.	1	2	3	4	5	6	7
9(15)	Je suis confiant(e) sur le fait que je suis capable de comprendre les éléments les plus complexes présentés par le formateur dans cette session.	1	2	3	4	5	6	7
10(17)	Je suis très intéressé(e) par le thème de cette session.	1	2	3	4	5	6	7
11(20)	Je suis confiant(e) sur ma capacité à faire un excellent travail concernant les exercices et les tests associés à cette session.	1	2	3	4	5	6	7
12(21)	Je compte bien faire dans cette session.	1	2	3	4	5	6	7
13(23)	Je pense qu'il est utile pour moi d'apprendre le matériel de cours de cette session.	1	2	3	4	5	6	7
14(26)	J'aime le sujet de cette session.	1	2	3	4	5	6	7
15(27)	Comprendre le sujet de cette session est très important pour moi.	1	2	3	4	5	6	7
16(29)	Je suis certain(e) que je peux maîtriser les compétences enseignées dans cette session.	1	2	3	4	5	6	7
17(30)	Je veux faire bien dans cette session, car il est important de démontrer ma capacité à ma famille, mes amis, mon employeur, ou autres.	1	2	3	4	5	6	7
18(31)	Compte tenu du niveau de difficultés de cette session, du formateur, et de mes compétences, je pense que je vais faire bien lors de cette session.	1	2	3	4	5	6	7

The English version, similar to the above French version, used in:
Fauquet-Alekhine, Ph. (2015) Harmful Threshold of ICT distraction on the Learning Process. Int. J. of Sc. and Engineering Investigations (IJSEI) 4(43), 62-69

Motivation

The following questions ask about your motivation for and attitudes about this lecture.
Remember there are no right or wrong answers, just answer as accurately as possible. Use the scale below to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

	items	assessment						
		1-Not at all true of me						7-Very true of me
		1	2	3	4	5	6	7
1(4)	I think I will be able to use what I learn in this lecture in other circumstances.	1	2	3	4	5	6	7
2(5)	I believe I will receive an excellent score in this experiment.	1	2	3	4	5	6	7
3(6)	I'm certain I can understand the most difficult material presented in the readings for this lecture.	1	2	3	4	5	6	7
4(7)	Getting a good score in this experiment is the most satisfying thing for me right now.	1	2	3	4	5	6	7
5(10)	It is important for me to learn the lecture material in this experiment.	1	2	3	4	5	6	7
6(11)	The most important thing for me right now is improving my overall score, so my main concern in this experiment is getting a good score.	1	2	3	4	5	6	7
7(12)	I'm confident I can learn the basic concepts taught in this lecture.	1	2	3	4	5	6	7
8(13)	If I can, I want to get better score in this experiment than most of the other participants.	1	2	3	4	5	6	7
9(15)	I'm confident I can understand the most complex material presented by the lecturer in this lecture.	1	2	3	4	5	6	7
10(17)	I am very interested in the content area of this lecture.	1	2	3	4	5	6	7
11(20)	I'm confident I can do an excellent job on the assignments and tests in this lecture.	1	2	3	4	5	6	7
12(21)	I expect to do well in this experiment.	1	2	3	4	5	6	7
13(23)	I think the lecture material in this experiment is useful for me to learn.	1	2	3	4	5	6	7
14(26)	I like the subject matter of this lecture.	1	2	3	4	5	6	7
15(27)	Understanding the subject matter of this lecture is very important to me.	1	2	3	4	5	6	7
16(29)	I'm certain I can master the skills being taught in this lecture.	1	2	3	4	5	6	7
17(30)	I want to do well in this experiment because it is important to show my ability to my family, friends, employer, or others.	1	2	3	4	5	6	7
18(31)	Considering the difficulty of this lecture, the lecturer, and my skills, I think I will do well in this experiment.	1	2	3	4	5	6	7

Appendix 10 : Psychological stress self-assessed by the Appraisal of Life Event Scale (ALES)

Psychological stress may be self-assessed by means of the Appraisal of Life Event Scale (ALES) just after experiencing an event. This scale was elaborated and validated by Ferguson et al. (1999).
The questionnaire consisted of 16 adjectives helping the subjects to rate the immediate experienced situation on a Likert scale according to two aspects: stress due to excitement and stress due to constrains. For this aim, the questionnaire formulates explicitly that the stress assessment relates to "the activity you were involved whilst going onto the simulator".
For each subject, a total score may be calculated by summing the circled answers and a mean score may be calculated per sample.

Copy of the questionnaire used in the present study

French version

Merci de remplir ce questionnaire en cochant la réponse la plus appropriée pour chaque question.

Nous nommons dans la suite « évènement » l'activité à laquelle vous venez de participer sur simulateur.

Indiquez dans quelle mesure chacun des adjectifs de la liste suivante décrit le mieux votre **perception de l'événement au moment où il s'est produit**, en entourant un des chiffres de cette échelle en 6 points :
0 1 2 3 4 5 correspondant aux extrêmes : 0 = **« pas du tout »** et 5 = **« extrêmement »**

Au moment où cet événement s'est produit, c'était :

		pas du tout	non	plutôt non	plutôt oui	oui	extrêmement
1	Menaçant	0	1	2	3	4	5
2	Provoquant (un défi)	0	1	2	3	4	5
3	Intolérable	0	1	2	3	4	5
4	Epouvantable	0	1	2	3	4	5
5	Agréable	0	1	2	3	4	5
6	Douloureux	0	1	2	3	4	5
7	Inquiétant	0	1	2	3	4	5
8	Stimulant	0	1	2	3	4	5
9	Déprimant	0	1	2	3	4	5
10	Hostile	0	1	2	3	4	5
11	Grisant	0	1	2	3	4	5
12	Pitoyable	0	1	2	3	4	5
13	Effrayant	0	1	2	3	4	5
14	Instructif	0	1	2	3	4	5
15	Terrifiant	0	1	2	3	4	5
16	Excitant	0	1	2	3	4	5

Copy of the questionnaire used in the present study

English version

Thank you for filling in this questionnaire by ticking the more appropriate answer for each question.

In the following, we shall call "event" the activity you were involved whilst going onto the simulator.

State how each of the adjectives of the following list described the best your perception of the event at the time it took place by encircling one of the number of the 6-point scale:

0 1 2 3 4 5 corresponding to the extremes: 0 = "not at all" and 5 = "extremely"

At the time the event took place, it was:

		Not at all	No	Rather no	Rather yes	yes	Extremely
1	threatening	0	1	2	3	4	5
2	challenging	0	1	2	3	4	5
3	intolerable	0	1	2	3	4	5
4	fearful	0	1	2	3	4	5
5	enjoyable	0	1	2	3	4	5
6	painful	0	1	2	3	4	5
7	worrying	0	1	2	3	4	5
8	stimulating	0	1	2	3	4	5
9	depressing	0	1	2	3	4	5
10	hostile	0	1	2	3	4	5
11	exhilarating	0	1	2	3	4	5
12	pitiful	0	1	2	3	4	5
13	frightening	0	1	2	3	4	5
14	informative	0	1	2	3	4	5
15	terrifying	0	1	2	3	4	5
16	exciting	0	1	2	3	4	5

Ferguson et al. (1999) differentiated the adjectives in 4 categories (p. 101):

THREAT	CHALLENGE	LOSS	BENEFIT
threatening	challenging	intolerable	exhilarating
fearful	enjoyable	painful	informative
worrying	stimulating	depressing	
hostile	exciting	pitiful	
frightening			
terrifying			

We found it more relevant to separate the adjectives in two categories as done elsewhere (Fauquet-Alekhine et al., 2015b):

CONSTRAINS	EXCITEMENT
threatening	challenging
fearful	enjoyable
worrying	stimulating
hostile	exciting
frightening	
terrifying	exhilarating
	informative
intolerable	
painful	
depressing	
pitiful	

Appendix 11 : Check-list objectifying required items for the assessment of the resulting competencies of residents' medical training

Fist version (15 items)

- Looks for and read the prescription.
- Prepares exhaustively the equipment
- Selects the specific syringe
- Consolidates the identity of the patient: name, bracelet (name, first name and date of birth).
- Requests the consent of the patient.
- Performs PHA hand friction (1 pulse) of at least 30 ''
- Puts a mask to the patient and to the physician according to the context
- Investigates the presence of local pain or injury.
- Performs ALLEN test
- Disinfects the puncture site with a sterile compress impregnated with alcoholic antiseptic.
- Look for absence of injection pain and sign of local edema.
- Ensures that there is no bubble in the syringe.
- Removes the syringe and seals with a sterile stopper
- Announces traceability of care
- Ergonomics, dexterity

Second version (52 items)

- Logs to the computer application to get the prescription
- Prepares exhaustively the equipment
- Selects the specific syringe
- Selects / Identifies the necessary equipment (especially recognizes the syringe, sterile compresses, alcoholic antiseptic solution)
- Organizes the material on a tray and / or trolley if necessary
- Organizes the space of the intervention (ex: lower the barriers of the bed)
- Consolidates the identity of the patient: name, bracelet (name, first name and date of birth)
- Requests the consent of the patient
- Explains the purpose of the intervention to the patient
- Performs PHA hand friction (1 pulse) of at least 30 ''
- Performs friction before touching compresses or other
- Analyzes monitoring parameters and estimates the feasibility of the intervention
- Stops or adjusts automatic monitoring / automatic blood pressure measurement
- Puts a mask to the patient according to the context
- Puts a mask to the physician according to the context
- Places the wrist in the optimal position
- Looks for local pain
- Investigates the presence of local lesions.
- Performs ALLEN test
- Adjusts comfort for puncture (sits, positions the tray / trolley)
- Selects the pulse from different sites (radial or other, right or left according to previous criteria)
- Undertakes a pulse search by applying two or three fingers in the axis of the artery
- Allows anatomical structures to recover between two palpations
- Opens the package of compresses (in the right way) to facilitate their imbibition together in the package
- Does not touch compresses
- Puts the antiseptic on the compresses in order to imbibe the whole package
- Threads gloves (normally sterile)
- Disinfects the puncture site with a sterile compress impregnated with antiseptic
- The disinfected area is wide (all the anterior zone of the wrist)
- Maintains the pre-set volume of the syringe
- The antiseptic used is alcoholic
- Ensures that there is no bubble in the syringe

- Re-palpates before stitching and does not lose the indication of the artery during the resumption of syringe (ex: keep a finger in support)
- Spikes in tangential (satisfactory angle: 45 °)
- Spikes in the opposite direction to blood flow
- Needle bevel upwards
- Strikes successfully at once
- Removes the syringe and protects the needle
- Removes the syringe and locks it with a sterile stopper
- Performs compression of the artery after puncture (prolonged)
- Compresses the artery immediately after puncture
- Places an efficient compressive dressing
- Immediately tags the syringe
- Traces the care in the patient's file
- Placement versus patient does not result in physician repositioning
- Placement in relation to the materials does not create any difficulties
- Gestures are fluid (good coordination, good linking)
- Most of the gestures was announced to the patient
- Has ability to negotiate and / or argue non-interruption of the task
- Resets the monitoring / automatic blood pressure / reconnects the patient
- Transmits sample quickly for analysis (ABG measurement requirements)
- Obtains the sample

Third and final version (28 items)

- Selects / Identifies the necessary equipment (especially recognizes the syringe, sterile compresses, alcoholic antiseptic solution)
- Consolidates the identity of the patient: name, bracelet (name, first name and date of birth)
- Requests the consent of the patient
- Explains the purpose of the intervention to the patient
- Performs PHA hand friction (1 pulse) of at least 30 ''
- Performs friction before touching compresses or other
- Undertakes a pulse search by applying two or three fingers in the axis of the artery
- Opens the package of compresses (in the right way) to facilitate their imbibition together in the package
- Does not touch compresses
- Puts the antiseptic on the compresses in order to imbibe the whole package
- Threads gloves (normally sterile)
- Disinfects the puncture site with a sterile compress impregnated with antiseptic
- The disinfected area is wide (all the anterior zone of the wrist)
- Ensures that there is no bubble in the syringe
- Re-palpates before stitching and does not lose the indication of the artery during the resumption of syringe (ex: keep a finger in support)
- Spikes in tangential (satisfactory angle: 45 °)
- Spikes in the opposite direction to blood flow
- Strikes successfully at once
- Removes the syringe and protects the needle
- Removes the syringe and locks it with a sterile stopper
- Performs compression of the artery after puncture (prolonged)
- Compresses the artery immediately after puncture
- Places an efficient compressive dressing
- Placement versus patient does not result in physician repositioning
- Placement in relation to the materials does not create any difficulties
- Gestures are fluent (good coordination, good linking)
- Most of the gestures was announced to the patient
- Obtains the sample

Appendix 12 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the medical activity “radial puncture”

Chps de compétences	Garantir que la prescription/le soin est pour le patient	Garantir la qualité de l’intervention pour le patient (6)	Remettre le patient en sécurité à la fin de l’intervention	Identifier le pouls pour choisir le site de ponction	Installer le matériel d’intervention (anticipation)	Désinfecter	Identifier le pouls radial pour pratiquer la ponction	piquer	Prélever le sang et comprimer	Sécuriser le prélèvement
S & SF individuels	Savoir se loguer à l’application pour obtenir la prescription Connaître le fonctionnement de l’application pour y obtenir/saisir les renseignements nécessaires Connaître le protocole d’identification du patient conscient (n° ch, n° patient, nom patient) pour garantir la cible (1) Connaître le protocole d’identification du patient inconscient (n° ch, n° patient, bracelet) pour garantir la cible (2)	Connaître le protocole de lavage des mains pour préserver le patient de la contamination manuportée (5) Connaître le fonctionnement du scope et les paramètres à lire dès l’entrée en contact du patient pour estimer la faisabilité et la difficulté de l’intervention (17) (18) Savoir argumenter la non interruption de tâche(3) Connaître les autres sites de ponction possibles en cas de difficulté de ponction radiale (4) Connaître les contre-indications au geste (pb de	Remettre les barrières Connaître les paramètres pertinents du scope pour reparamétrer éventuellement le scope	Connaître le point de palpation du pouls radial Connaitre la position de poignet du patient optimale pour optimiser Etre conscient que le pouls radial peut être meilleur à droite ou à gauche pour palper les deux et faire un choix Connaître le geste à 2 à 3 doigts répété (laisser les structures se remettre en place) pour une palpation optimale (16) Savoir qu’un hématome peut réduire la palpation du pouls	Connaître les éléments nécessaires à l’intervention pour les placer à porter de main (15) Connaître ses capacités pour choisir d’utiliser le chariot à côté du lit ou un plateau sur le lit du patient et pour mettre éventuellement un petit drap sous le bras du patient Etre conscient que le pouls radial peut être meilleur à droite ou à gauche pour faire le choix de déplacer le matériel du côté optimal (11) Connaître les différentes seringues pour identifier/reconnaître celle adaptée aux GDS	Connaître les critères d’asepsie pour imbiber et manipuler les compresses de manière adaptée et désinfecter une large zone de peau et évacuer la compresse usagée ailleurs (13) Connaître la capacité d’intégration de liquide des compresses pour verser la quantité d’antiseptique nécessaire à l’imbibition de plusieurs (14)	Connaître le point de palpation du pouls radial Connaitre la position de poignet du patient optimale pour faciliter la palpation Connaître le geste à 2 à 3 doigts répété (laisser les structures se remettre en place) pour une palpation optimale (16) Etre conscient que 3 doigts vont matérialiser une ligne virtuelle parallèle à l’artère recherchée pour une ponction optimale	Etre conscient de l’importance de la palpation et de l’identification du point de ponction pour toujours laisser un doigt (annulaire) au contact de la peau (19) Connaître le sens du flux dans l’artère pour pratiquer la ponction (piquer) dans le bon sens de façon tangentielle (20) Connaître le réglage préalable de la seringue pour maintenir le volume préréglé de prélèvement dans la seringue Connaître l’ergonomie de	Connaître les caractéristiques du sang artériel pour reconnaître et valider la ponction en cours (22) Connaître les caractéristiques du sang artériel pour comprimer immédiatement après le prélèvement(23) Connaître les caractéristiques du sang artériel pour aménager un pansement compressif à l’aide d’un large morceau de scotch.	Connaître l’ergonomie de la seringue et le protocole associé pour la refermer en conformité et éventuellement extraire la présence d’air excédant Connaître les impératifs et les risques d’erreurs pour étiqueter immédiatement le flacon.

		coagulation) Connaître les autres sites de ponction déconseillés (eg numéral) pour éviter des aggravations Savoir ce qui fait le confort du patient pour rectifier sa position, rectifier/remettre ses branchements (même inconscient) (=non-objet) (6) Connaître les détails qui vont faciliter l'intervention (7) Connaitre les éléments perturbant l'intervention (8) Connaitre les détails qui vont rassurer le patient pour les lui communiquer, parler avec le patient, annoncer chaque geste Connaitre les détails qui optimisent l'intervention du fait du patient le		Connaître les facteurs qui vont permettre de choisir le site de ponction (9)	Connaître les différentes compresses pour choisir celles stériles Connaître le conditionnement des compresses pour ouvrir partiellement le paquet sans toucher les stériles en posant le paquet avec le côté préformé vers le bas (12) Connaître les différents désinfectants pour choisir celui alcoolisé			la seringue pour l'ouvrir puis la tenir dans le sens optimal (biseau d'aiguille vers le haut) sans quitter le contact de la peau (auriculaire) Connaître les caractéristiques d'une artère pour pratiquer la ponction (piquer) de façon tangentielle sans la traverser (20) Etre conscient de la nécessité de stabilisation pour appuyer l'auriculaire stabilisant la main (19) Savoir que le passage de l'aiguille dans le bras peut être perçu par les doigts qui palpent pour obtenir de l'information sur sa progression. Connaître les possibilités des		

		pour les lui communiquer, (eg ne pas bouger) Savoir qu'une plaie, un hématome, peut détériorer la qualité de l'intervention (douleur) = test d'Alfen ?						structures internes du bras pour réorienter l'aiguille au besoin sans repiquer (21)		
S & SF collectifs					Connaître les facteurs nécessitant d'appeler l'aide d'un tiers (10)					Connaître les impératifs de la mesure GDS pour transmettre rapidement l'échantillon à la bonne personne

(1) A.File à 10 :00
(2) le nom du patient sur le scope n'est pas fiable.
(3) il faut savoir ne pas se laisser interrompre dans cette tâche courte (eg. répondre au téléphone, sortir).
(4)A.File à 18 :00 ;
(5) solution hydroalcoolique pendant 30''
(6) s'inquiéter du confort pour le patient est un complément fondamental car aide à mettre en œuvre mentalement ce qui fait du patient un être humain et non un objet (humain : non-objet) et donc participe à son confort.
(7) eg. Baisser les barrières.
(8) eg. Annuler la prise de tension ou la reprogrammer.
(9) droite, gauche, radial un autre + confort de l'intervenant pour pratiquer l'acte (pas facile à gauche pour droitier).
(10) pratiquer à gauche pour un droitier peut nécessiter d'être deux (A.File à 29 :30).
(11) A.File à 32 :00
(12) le côté préformé fait récipient et maintien les compresses dans le paquet ainsi que le désinfectant.
(13) eg. Ne pas toucher la compresse avec l'embout du flacon d'antiseptique.
(14) plusieurs compresses avec désinfectant seront nécessaires.
(15) compresses imbibées, seringue, scotch, étiquette d'identification du prélèvement.
(16) pas un seul doigt (A.File à 53 :00)
(17) faible tension = pouls difficile à palper.
(18) absence d'alarme, fréquence cardiaque, saturation et tension correctes (A.File à 58 :00)
(19) ex : V.File à 03 :06 : 2 doigts stabilisent : l'auriculaire pour la main et l'annulaire pour le point de ponction au moment de la manipulation de la seringue.
(20) permet d'éviter de transpercer l'artère
(21) A.File 01 :22 :30 et V.File 04 :00
(22) débit du fait de la pression artérielle (la veine est plus faible et une veine peut avoir été traversée sur la trajectoire choisie), couleur rouge et non noire.
(23) appuyer aussi fort que avec de deux sur l'arête du nez juste avant que cela fasse mal.

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	50
Collective knowledge	2
Tacit/explicit differentiation	32.7%
Replay interview duration (min.)	about 90
Total time for meeting (min.)	about 120

Appendix 13 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Application of Reliability Practices"

Position: pilot and field worker

Reliability Practices are six:
Pre job briefing (PjB), Take a Minute (TM), Self-Control (SC), Cross-Control (CC), Three-Way-Communication (TWC), Debriefing (Deb). A matrix was provided for each of them and the first one gathers the common K & KH to all.
Some of them require two interactants (PjB, CC, TWC, Deb): the matrix is provided from the worker's standpoint performing the activity.
The final count considers the six practices.

All RP	Apply the overall meaning of the RP	Gather the necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing the meaning and added value of each RP to implement them properly both in form and substance Being aware of the importance of targeting the implementation of the RP during the preparation of the activity to apply the RP at appropriate times and put into discussion with the management at PJB (implies: do not just focus on the activity) Knowing the expected RP ideally to implement it closer to this ideal Being aware of the anticipatory nature of the RP to implement them before the action. Knowing the rationales of application of RP so that its implementation does have meaning	Knowing the existence of RP notebook to use it if needed Being aware that fatigue and time pressure are factors necessitating the RP (not the opposite) to actually make reliable the activity Knowing the Other's watch to take the RP notebook and use it if needed		
K & KH collective	Knowing what the management expects to apply the RP at appropriate times Being aware of the importance of targeting the implementation of a RP to apply the RP at appropriate times			

PjB (performer)	Apply the overall meaning of the RP	Gather the necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing that the PJB is a mental preparation for anticipating problems and a projection into the activity to implement this RP whilst understanding its meaning	Being aware of the importance of self-projection as a performer in the upcoming activity to anticipate difficulties Knowing where to find information describing the purpose of the activity to be able to expose and develop the mental representation of what is to be done Being aware of own doubt to be able to make it visible (eg prime-performer) to implement or have implemented the necessary remedials	Being aware of the importance of writing on the MO the times at which it is agreed to apply a RP to ensure effective implementation at the appropriate time Being critical to discuss the request for application of some RP for the interlocutor gives meaning to this application request Being aware of the possible benefits/drawbacks of the RP to discuss the application request for some RP and possibly refuse them in order to not be cognitively overloaded or suggest another remedial Knowing the purpose of the activity and have understood it to expose it to the interlocutor	
K & KH collective		Knowing the interlocutor to make sure this person is able to complete / argue / explain the purpose of the activity to make sense of what needs to be done and to contribute in a correct elaboration of the mental representation of what will be done Knowing the interlocutor to make sure this person is able to confirm that the interlocutor has understood what needs to be done (understood the meaning of the activity) Knowing the importance of a joint venture to PJB to choose a suitable place for the PJB to enable stakeholders to discuss face to face (and not in line with the manager between stakeholders which necessarily involves turning the back on someone)	Being aware of the importance of the sense of action to ask the interlocutor the meaning of a request to apply a RP so that the interlocutor makes sense to future action	

TM	Apply the overall meaning of the RP	Gather the necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing that TM is a break (no precipitation) to implement this RP understanding its meaning	Knowing the times when the TM is beneficial to be able to apply it at these times	Knowing what to look at in a 360 ° watch to achieve effective TM Knowing that the emergency means (exit, devices, alert system) are important elements of the TM in order to achieve effective TM Being aware that sometimes the TM involves nesting other RP in order to be effective (eg SC for identification of premises) Knowing the difference between a TM before intervention, TM after interruption and TM for the unexpected event to look for relevant information during implementation of the TM	
K & KH collective				

SC	Apply the overall meaning of the RP	Gather the necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing that the SC is to control the adequacy between the MO and the action planed to implement the RP whilst understanding its meaning	Knowing the difference between SC, CC and other types of control in order to understand the action to come and apply it in accordance with what is expected Being aware that repetitive RP as the SC may become routine to remain vigilant about a conform application of SC during the action	Knowing when it is important to read the label of the equipment to support the meaning of the action and to promote a SC based on the understanding of action in addition to reading Knowing the difference between overall reading and syllabic reading to implement the RP understanding its meaning Knowing the function of pointing the finger (or other object) of the syllable read to achieve effective syllabic reading (cutting the object to be read) Knowing the importance of looking precisely what is read in order to achieve effective syllabic reading Being aware that the SC is a syllabic reading of the MO (source) and of the equipment label (target) to achieve an effective comparison between source and target Knowing the importance of keeping the finger on the equipment (or other means of identification) once it is identified in order not to mismatch the target if it is necessary to read or watch something else before the action	
K & KH collective				

CC	Apply the overall meaning of the RP	Gather the necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing that CC is a visual check by a another person between the intended action and the draft action to implement the RP understanding its meaning Knowing that CC is a visual check by a another person between the intended action and the draft action in order not to be overloaded with other RP (eg it can avoid asking the other person to implement a SC on the MO while it was just done)	Knowing the difference between SC, CC and other types of control in order to understand the action to come and apply it in accordance with what is expected	Being aware that sometimes the CC involves nesting other RP in order to be effective (eg TWC on oral exchange) Being aware that the CC involves to check the oral intention and the draft action to be effective	
K & KH collective		Being aware that the CC involves another person to provide the necessary resources		

TWC	Apply the overall meaning of the RP	Gather he necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing that TWC is the assurance that the oral message is received to implement the RP understanding its meaning	Being aware of its own limits to require TWC when ones feels the need (doubt) even when the interlocutor does not seem to be willing to guarantee the reliability of the activity (erasing the doubt)	Knowing the difference between repetition and reformulation to achieve this RP effectively Being aware of the importance of the target, the action, the deadline in the message so that the RP is effective Understanding the importance of the final phrase ("it's correct") so that the RP is effective Identifying what is important as elements that must constitute the message (target, action, time)	
K & KH collective				

Deb (performer)	Apply the overall meaning of the RP	Pull together the necessary conditions to the effectiveness of the RP	Implement the technique of RP	
K & KH individual	Knowing that the Deb is a time for integration of the operational feedback to implement this RP understanding its meaning		Being critical to discuss the application request for some RP to refuse them in order to not be cognitively overloaded	
K & KH collective		Knowing the importance of a joint venture to Deb to choose a suitable place for the Deb to enable stakeholders to discuss face to face (and not in line with the manager between stakeholders which necessarily involves turning the back on someone)		

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	54
Collective knowledge	8
Tacit/explicit differentiation	17.7%

Appendix 14 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Hydraulic configuration"

Position: pilot

Individual level of the activity					
Fields of competencies	Use a MO with its various parts to fill in	Understand the control panel	Act on the control-command	Develop the overall representation of the state of the process	Ensure the nuclear safety level required
Individual K & KH	-reading (in advance) and understanding what is asked to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality -knowing the importance of traceability and the impact of lack of traceability to fill in and sign the form correctly	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related industrial process to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing the specificities of equipment in order to read information and/or to act on the control-command properly -being aware of specific physical phenomena subsequent to certain control-command actions to avoid doing too much or doing too slow(1) -being aware of potential risk of action to make it reliable efficiently with no excess -be aware of the forthcoming actions to anticipate them	-knowing the physical process to understand physical phenomena -knowing the relevant physical parameters to check to identify/understand the changes of physical phenomena -knowing the equipment related to the physical parameters	-knowing the general operating and technical specifications (OTS) to perform a relevant and efficient check-up -knowing the amendments of OTS to perform a relevant and efficient check-up

Collective level of the activity							
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker's need	Manage several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one's role	-knowing the means at disposal to communicate in due time and correctly(2) -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be -being conscious that waiting may demotivate to give periodical information to the field-worker(3)	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

(1)Following actions on certain control-command equipment in the control room, consecutive physical phenomena may be very slow engaging sometimes novices to act again on the control-command (doing too much) and leading to an excessive resulting action. Conversely, some novices may be afraid of doing too much and act carefully but slowly on the control-command; it may be sometimes too slow (doing too slow) to counteract an unexpected physical change of the installation.
(2)Using the control-panel as a visual support for oral communication may be a means.
(3)The pilot may ask sometimes the field worker to stay in a place in case of need. If waiting lasts long, the pilot must think to call and explain why.

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	17
Collective knowledge	23
Tacit/explicit differentiation	51.2%
Replay interview duration (min.)	about 40
Total time for meeting (min.)	about 60

Appendix 15 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Hydraulic configuration"

Position: field worker

Individual level of the activity						
Fields of competencies	Use a MO with its various parts to fill in	Move on the plant	Prepare the documents	Identify the equipment	Recognize Lock & Tag[26] for equipment	Act on the equipment
Individual K & KH	-reading (in advance) and understanding what is asked to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality -knowing the importance of traceability and the impact of lack of traceability to fill in and sign the form correctly	-knowing the isometry of buildings to find the equipment through the shortest way -knowing the nomenclature of premises to find the equipment using the MO -knowing which equipment is associated with specific physical process to mentalize the location of the equipment and then find it quicker - knowing which equipment is associated with specific physical process to read and understand more easily a mechanical drawing	-knowing the documentation organization to complement the documents provided for the activity if need be -knowing the implicit standard of color to apply relevant colors on the mechanical drawing to make it simpler to read in the field -understanding the mechanical drawing to make an understandable link with the MO - understanding the mechanical drawing to translate it as a MO	-knowing the benefits of exchanging with colleagues before going into the field to find faster the equipment -knowing the best practices applied to identify the equipment to identify it without doubt(2) -knowing the rules and the tags used to tag the equipment to read/interpret a functional tag -knowing the benefits of having in the field a mechanical drawing to find faster the equipment	-knowing the rules and the tags used to tag the equipment to recognize a sign of lockout -knowing the organizational principles of lock & tag to comply with the prescriptions(3) -being conscious of the implications of a missed lock & tag work to verify the lock & tag if need be	-knowing the specificities of equipment in order to read and understand information and/or to act on the equipment -knowing what is asked and means to compare it with what can be done (especially when several tasks may opposed each other) - knowing risks related to action on equipment to avoid unexpected issue - knowing when to act on equipment to avoid surprising movement of liquid for the pilot -being aware of potential risk of action to make it reliable efficiently with no excess -knowing the physical expressions of the equipment operating in order to understand information and/or to act on the equipment -be conscious of the separation diagnosing/ repairing or locking/unlocking to perform the expected phase without slipping to the next one -knowing the fundamentals of configuring to structure activity (including considering purges and vents) -knowing the key points of the activity to perform a efficient final control

[26] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a lock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

Collective level of the activity							
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker's need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one's role	-knowing the means at disposal to communicate in due time and correctly -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	27
Collective knowledge	23
Tacit/explicit differentiation	54.0%

Appendix 16 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity “Electric configuration (cell lock out)”

Position: pilot

Individual level of the activity			
Fields of competencies	Understand the control panel	Act on the control-command	Ensure the nuclear safety level required
Individual K & KH	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related industrial process to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing the specificities of equipment in order to read information and/or to act on the control-command properly -being aware of specific physical phenomena subsequent to certain control-command actions to avoid doing too much or doing too slow(1) -being aware of potential risk of action to make it reliable efficiently with no excess -be aware of the forthcoming actions to anticipate them	-knowing the general operating and technical specifications (OTS) to perform a relevant and efficient check-up -knowing the amendments of OTS to perform a relevant and efficient check-up

Collective level of the activity							
Fields of competencies	Use co-workers’ competencies	Share the representation of the activity	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker’s need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers’ competencies to make judicious requests -being conscious of the peers’ possible help to ask co-workers’ help asap -knowing own limits to let co-workers’ do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one’s role	-knowing the means at disposal to communicate in due time and correctly(2) -being conscious of the co-worker’s workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker’s need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be -be conscious that waiting may demotivate to give periodical information to the field-worker(3)	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

(1)Following actions on certain control-command equipment in the control room, consecutive physical phenomena may be very slow engaging sometimes novices to act again on the control-command (doing too much) and leading to an excessive resulting action. Conversely, some novices may be afraid of doing too much and act carefully but slowly on the control-command; it may be sometimes too slow (doing too slow) to counteract an unexpected physical change of the installation.
(2)Using the control-panel as a visual support for oral communication may be a means.
(3)The pilot may ask sometimes the field worker to stay in a place in case of need. If waiting lasts long, the pilot must think to call and explain why.

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	12
Collective knowledge	24
Tacit/explicit differentiation	61.1%

Appendix 17 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Electric configuration (cell lock out)"

Position: field worker

Individual level of the activity					
Fields of competencies	Use a MO with its various parts to fill in	Move on the plant	Identify the equipment	Implement Lockout-Tagout[27] for equipment	Act on the equipment
Individual K & KH	-reading (in advance) and understanding what is asked to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality -knowing the importance of traceability and the impact of lack of traceability to fill in and sign the form correctly	-knowing the isometry of buildings to find the equipment through the shortest way -knowing the nomenclature of premises to find the equipment using the MO -knowing which equipment is associated with specific physical process to mentalize the location of the equipment and then find it quicker - knowing which equipment is associated with specific physical process to read and understand more easily a mechanical drawing	-knowing the benefits of exchanging with colleagues before going into the field to find faster the equipment -knowing the best practices applied to identify the equipment to identify it without doubt(2) -knowing the rules and the tags used to tag the equipment to read/interpret a functional tag	-knowing the rules and the tags used to tag the equipment to recognize a sign of lockout -knowing the rules to lock & tag a piece of equipment from the technical standpoint to obtain a quality result -knowing the organizational principles of lock & tag to comply with the prescriptions(3) -being conscious of the implications of a missed lock & tag work to be motivated to obtain a quality result -knowing which locks are required to equip oneself correctly	-knowing the specificities of equipment in order to read and understand information and/or to act on the equipment -knowing what is asked and means to compare it with what can be done (especially when several tasks may opposed each other) - knowing risks related to action on equipment to avoid unexpected issue -being aware of potential risk of action to make it reliable efficiently with no excess -knowing the fundamentals of lock & tag to structure activity -being conscious of emotions induced by risks to manage them -knowing the key points of the activity to perform a efficient final control -knowing which equipment is concerned to select locks and tags

[27] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a lock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

Collective level of the activity								
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Cope with lack of knowledge	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker's need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-knowing colleagues' competencies to obtain relevant help	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one's role	-knowing the means at disposal to communicate in due time and correctly -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be -be conscious that waiting may demotivate to give periodical information to the field-worker(3)	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	22
Collective knowledge	25
Tacit/explicit differentiation	47.9%

Appendix 18 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "periodical test"

Position: pilot

Individual level of the activity					
Fields of competencies	Use a MO with its various parts to fill in	Understand the control panel	Cope with lack of knowledge	Act on the control-command	Ensure the nuclear safety level required
Individual K & KH	-reading (in advance) and understanding what is asked to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality -knowing the importance of traceability and the impact of lack of traceability to fill in and sign the form correctly	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related industrial process to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing in which documents or data base find the answer(s) in order to undertake a relevant analysis	-knowing the specificities of equipment in order to read information and/or to act on the control-command properly -being aware of specific physical phenomena subsequent to certain control-command actions to avoid doing too much or doing too slow(1) -being aware of potential risk of action to make it reliable efficiently with no excess -be aware of the forthcoming actions to anticipate them	-knowing the general operating and technical specifications (OTS) to perform a relevant and efficient check-up -knowing the amendments of OTS to perform a relevant and efficient check-up -being conscious of possible distractions to implement recalling means

Collective level of the activity								
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Cope with lack of knowledge	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker's need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-knowing colleagues' competencies to obtain relevant help	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one's role	-knowing the means at disposal to communicate in due time and correctly(2) -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be -being conscious that waiting may demotivate to give periodical information to the field-worker(3)	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

(1)Following actions on certain control-command equipment in the control room, consecutive physical phenomena may be very slow engaging sometimes novices to act again on the control-command (doing too much) and leading to an excessive resulting action. Conversely, some novices may be afraid of doing too much and act carefully but slowly on the control-command; it may be sometimes too slow (doing too slow) to counteract an unexpected physical change of the installation.
(2)Using the control-panel as a visual support for oral communication may be a means.
(3)The pilot may ask sometimes the field worker to stay in a place in case of need. If waiting lasts long, the pilot must think to call and explain why.

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	17
Collective knowledge	25
Tacit/explicit differentiation	52.3%

Appendix 19 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "periodical test"

Position: field worker

Individual level of the activity						
Fields of competencies	Use a MO with its various parts to fill in	Move on the plant	Identify the equipment	Recognize Lock & Tag[28] for equipment	Act on the equipment	Prepare the documents
Individual K & KH	-reading (in advance) and understanding what is asked to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality -knowing the importance of traceability and the impact of lack of traceability to fill in and sign the form correctly	-knowing the isometry of buildings to find the equipment through the shortest way -knowing the nomenclature of premises to find the equipment using the MO -knowing which equipment is associated with specific physical process to mentalize the location of the equipment and then find it quicker - knowing which equipment is associated with specific physical process to read and understand more easily a mechanical drawing	-knowing the benefits of exchanging with colleagues before going into the field to find faster the equipment -knowing the best practices applied to identify the equipment to identify it without doubt(2) -knowing the rules and the tags used to tag the equipment to read/interpret a functional tag -knowing the benefits of having in the field a mechanical drawing to find faster the equipment	-knowing the rules and the tags used to tag the equipment to recognize a sign of lockout -knowing the organizational principles of lock & tag to comply with the prescriptions(3) -being conscious of the implications of a missed lock & tag work to verify the lock & tag if need be	-knowing the specificities of equipment in order to read and understand information and/or to act on the equipment -knowing what is asked and means to compare it with what can be done (especially when several tasks may opposed each other) - knowing risks related to action on equipment to avoid unexpected issue -being aware of potential risk of action to make it reliable efficiently with no excess - knowing when to act on equipment to avoid surprising movement of liquid/electric change/alarm for the pilot -knowing the physical expressions of the equipment operating in order to understand information and/or to act on the equipment -being conscious of the separation diagnosing/ repairing or locking/unlocking to perform the expected phase without slipping to the next one -knowing the fundamentals of periodical tests to structure activity -knowing the key points of the activity to perform a efficient final control	-knowing the documentation organization to complement the documents provided for the activity if need be -knowing the implicit standard of color to apply relevant colors on the mechanical drawing to make it simpler to read in the field -understanding the mechanical drawing to make an understandable link with the MO - understanding the mechanical drawing to translate it as a MO
Collective level of the activity						

[28] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a lock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Cope with lack of knowledge	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker's need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues)	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-knowing colleagues' competencies to obtain relevant help	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one's role	-knowing the means at disposal to communicate in due time and correctly(2) -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

(2)Using the control-panel as a visual support for oral communication may be a means.

Method ->	SEBE/SPEAC-based method
Individual knowledge	27
Collective knowledge	24
Tacit/explicit differentiation	54.0%

Appendix 20 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity “Lock out (hydraulic)”

Position: pilot

Individual level of the activity			
Fields of competencies	Understand the control panel	Act on the control-command	Ensure the nuclear safety level required
Individual K & KH	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related industrial process to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing the specificities of equipment in order to read information and/or to act on the control-command properly -being aware of specific physical phenomena subsequent to certain control-command actions to avoid doing too much or doing too slow(1) -being aware of potential risk of action to make it reliable efficiently with no excess -be aware of the forthcoming actions to anticipate them	-knowing the general operating and technical specifications (OTS) to perform a relevant and efficient check-up -knowing the amendments of OTS to perform a relevant and efficient check-up

Collective level of the activity							
Fields of competencies	Use co-workers’ competencies	Share the representation of the activity	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker’s need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers’ competencies to make judicious requests -being conscious of the peers’ possible help to ask co-workers’ help asap -knowing own limits to let co-workers’ do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one’s role	-knowing the means at disposal to communicate in due time and correctly(2) -being conscious of the co-worker’s workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker’s need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be -being conscious that waiting may demotivate to give periodical information to the field-worker(3)	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

(1)Following actions on certain control-command equipment in the control room, consecutive physical phenomena may be very slow engaging sometimes novices to act again on the control-command (doing too much) and leading to an excessive resulting action. Conversely, some novices may be afraid of doing too much and act carefully but slowly on the control-command; it may be sometimes too slow (doing too slow) to counteract an unexpected physical change of the installation.

(2)Using the control-panel as a visual support for oral communication may be a means.

(3)The pilot may ask sometimes the field worker to stay in a place in case of need. If waiting lasts long, the pilot must think to call and explain why.

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	12
Collective knowledge	24
Tacit/explicit differentiation	55.5%

Appendix 21 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Lock out (hydraulic)"

Position: field worker

Individual level of the activity						
Fields of competencies	Move on the plant	Prepare the documents	Use a MO with its various parts to fill in	Implement Lock & Tag[29] for equipment	Identify the equipment	Act on the equipment
Individual K & KH	-knowing the isometry of buildings to find the equipment through the shortest way -knowing the nomenclature of premises to find the equipment using the MO -knowing which equipment is associated with specific physical process to mentalize the location of the equipment and then find it quicker - knowing which equipment is associated with specific physical process to read and understand more easily a mechanical drawing	-knowing the documentation organization to complement the documents provided for the activity if need be -knowing the implicit standard of color to apply relevant colors on the mechanical drawing to make it simpler to read in the field -understanding the mechanical drawing to make an understandable link with the MO - understanding the mechanical drawing to translate it as a MO	-reading (in advance) and understanding what is asked to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality -knowing the importance of traceability and the impact of lack of traceability to fill in and sign the form correctly	-knowing the rules and the tags used to tag the equipment to recognize a sign of lockout -knowing the rules to lock & tag a piece of equipment from the technical standpoint to obtain a quality result -knowing the organizational principles of lock & tag to comply with the prescriptions(3) -being conscious of the implications of a missed lock & tag work to be motivated to obtain a quality result	-knowing the benefits of exchanging with colleagues before going into the field to find faster the equipment -knowing the best practices applied to identify the equipment to identify it without doubt(2) -knowing the rules and the tags used to tag the equipment to read/interpret a functional tag -knowing the benefits of having in the field a mechanical drawing to find faster the equipment	-knowing the specificities of equipment in order to read and understand information and/or to act on the equipment -knowing what is asked and means to compare it with what can be done (especially when several tasks may opposed each other) - knowing risks related to action on equipment to avoid unexpected issue -being aware of potential risk of action to make it reliable efficiently with no excess - knowing when to act on equipment to avoid surprising movement of liquid for the pilot -knowing the physical expressions of the equipment operating in order to understand information and/or to act on the equipment -knowing which locks are required to equip oneself correctly -being conscious of the separation diagnosing/ repairing or locking/unlocking to perform the expected phase without slipping to the next one -knowing the fundamentals of lock & tag to structure activity -knowing the key points of the activity to perform a efficient final control -knowing which equipment is concerned to select locks and tags

[29] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a lock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

Collective level of the activity								
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Cope with lack of knowledge	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Take care of the co-worker's need	Managing several tasks in parallel	Share the operational feedback
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-knowing colleagues' competencies to obtain relevant help	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points -knowing the possible responsibilities of each one to define each one's role	-knowing the means at disposal to communicate in due time and correctly -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

Method ->	SEBE/SPEAC-based method
Individual knowledge	30
Collective knowledge	24
Tacit/explicit differentiation	52.8%

Appendix 22 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "Alarm treatment"

Position: pilot

Individual level of the activity					
Fields of competencies	Identify an alarm	Adopt the appropriate behavior	Read an alarm memo	Apply the alarm memo	
Individual K & KH	-knowing the rules related to the appearance of an alarm (implication of the color, of the letter "D" on alarm) in order to engage the appropriate actions	-knowing what is expected (by the management, the national regulator, the prescriptions) to make the right decision when it seems possible to cope with the situation without applying the alarm memo	-knowing the documentary system in which fits the alarm memos -knowing the reading rules of an alarm memo in order to interpret it	-knowing the documentary system to find the complementary documentation needed -knowing where to find information -knowing the relation between control equipment and related process equipment -understanding information, fast sometimes -knowing what must not be touch	
Collective level of the activity					
Fields of competencies	Use co-workers' competencies	Adopt the appropriate behavior			
Collective K & KH	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do -knowing the possible consequences of action whilst doubting to avoid potential mistake (ie: stop and ask colleagues	-knowing colleagues' competencies in order to quickly ask advice to the right person			

Method ->	SEBE/SPEAC-based method
Individual knowledge	9
Collective knowledge	5
Tacit/explicit differentiation	21.4%

Appendix 23 : Outcome Matrix {Fields of competencies VS Knowledge & Know-how} for the NPP activity "periodical test EP RGL4"

Position: Test technician

Competence fields	Anticiper de l'EP en salle de commande	Interpréter les données	Résoudre un problème hors compétences propres	Gérer la phase d'EP en SdC face à/avec la Conduite	Dépouiller des données par SAPEC	Collaborer en binôme
Knowledge (individual aspect)	• connaître les contraintes à venir de l'EP pour demander une Tmoy attendue au plus bas dans la plage autorisée : Tmoy=304 6°C (1) • connaître les contraintes à venir de l'EP pour demander un niveau RCV02BA suffisamment haut (2) • comprendre les conditions prescrites pour réaliser l'EP en conformité • connaître les critères de validation d'un point haut valable pour la G3 pour identifier une valeur fausse et la rejeter le cas échéant (4) • connaître les critères de validation d'un point haut valable pour la G3 pour argumenter une ré-acquisition(4) • connaître les phénomènes physiques pour identifier les valeurs pertinentes à mettre en suivi au KIT • avoir lu les résultats du Bil100 pour reconnaître les conditions adéquates de l'EP • connaître les phénomènes physiques pour identifier des valeurs de tension recevables/erronées (6) • connaître les phénomènes physiques pour comprendre le but de l'EP	• connaître l'objet et l'allure attendue par rapport au cycle des courbes G3 et G5 pour identifier une variation non souhaitée dans l'EP • connaître les fondamentaux des régulations GRE(3) et DMA pour interpréter les réactions de l'installation • connaître les phénomènes physiques pour identifier en suivi au KIT les valeurs satisfaisantes/déviantes par rapport à l'attendu (1)	• connaître ses limites pour identifier que le problème est hors compétences propres • connaître l'organisation pour identifier qui appeler à l'aide	• connaitre les phases et la méthode d'un PjB ainsi que la chronologie du MO (9) pour les mettre en lien • Etre conscient de l'importance de rester vigilant pendant les 30min (8) afin de détecter au plus vite tout fortuit • connaître les fondamentaux des régulations GRE(3) pour pouvoir comprendre la situation et s'en assurer côté Conduite aussi • connaître les standards de la CS pour l'appliquer lors des échanges (10) • être conscient que plusieurs observateurs seront en salle de commande pour faire fi des spectateurs (11) • être conscient de l'importance de cocher sa gamme d'EP au fur et à mesure (dans le gros classeur) pour obtenir un travail de qualité et tracé(12) • être conscient de l'importance de donner un top clair d'arrêt de baisse de charge (fin de l'EP) à l'Op pour coopérer efficacement • connaître les consignes appropriées pour les communiquer au bon moment à l'Op afin qu'il reprenne la conduite du pilotage • connaître les facteurs majeurs provoquant des variations de puissance avant l'EP (pendant l'EP, les variations sont gérées par le limiteur) afin d'anticiper les difficultés	• maîtriser le formalisme du logiciel pour l'utiliser efficacement (compagnonnage) • connaître les différents modes de dépouillement possibles pour justifier le choix du mode (compagnonnage)	
Knowledge (collective aspect)			• connaître l'organisation pour identifier quel métier appeler à l'aide • pendant la phase d'EP en salle de commande, connaître l'importance de l'apport des TOR pour justifier qu'ils soient prêts au déblocage du DMA	• connaître l'organisation à caler pour identifier au PjB qui fait quoi côté Essais et aussi côté Conduite(5) • connaître le sujet traité pour maîtriser le PjB face à OP, CE, CED qui questionnent(7) • coannître les standards de la CS lors des échanges pour l'exiger de l'Op (10)	• connaître l'importance de saisir les bonnes valeurs (et les conséquences en cas d'erreur) pour implémenter une CC sur la saisie des valeurs avec le co-intervenant	• connaître l'organisation à caler pour identifier les rôles et responsabilités • être conscient de l'apport des informations données par le collègue pour savoir les utiliser à bon escient • être conscient de l'apport de l'assistant (sa

						contribution à la surveillance de paramètres, ses alertes, son analyse…) pour savoir l'utiliser à bon escient

(1)Risque de devoir stopper l'EP pour éviter dépassement seuil haut Tmoy car lors de la baisse de charge, Tmoy croît. Pendant la phase d'EP en SdC, il faut être 2.
(2)RCV pourrait faire un appoint si niveau trop bas et donc perturber la stabilité recherchée (il faut N RCV >1.40, information noyée dans le MO).
(3)auto-manu-direct
(4)à implanter par les TOR en préalable à l'acquisition des données pour le calcul de la nouvelle G3.
(5)quel Op sera l'interlocuteur : important car on ne s'adresse pas de la même manière à un tiers et à son futur collaborateur ; idem pour répondre aux questions. En l'occurrence, l'un des Op était jugé trop jeune pour participer à l'EP par le sujet or c'est lui qui a fait.
(6)Identifier des valeurs de tension erronées par comparaison entre mesures au multimètre entrées dans SAPEC et celles disponibles en SdC. Il serait bien de noter quelque part qu'il faut s'assurer que la position des groupes R, G1 et G2 sur les pré-acquisitions SAPEC corresponde à la position des groupes en SdC (possible notamment lors des premiers EP RGL4 du cycle).
(7)exposant ; requiert de l'assurance.
(8) « C'est exotique, inhabituel pour tous : ça cavale, en 30min. c'est soldé alors que d'autres EP durent plusieurs jours et donnent le temps de regarder. »
(9)avec description des apparitions d'AA, des critères d'arrêt de l'EP.
(10) les standards de la CS lors des échanges procurent un réel confort et un gain de temps : pas de vérification ou de re-questionnement nécessaire.
(11) « il peut y avoir un troupeau derrière » : des Op qui n'ont jamais fait et qui veulent voir, des Op/CE/CED en supervision de celui qui fait, des Tech Essais à former.
(12)le gros classeur contenant l'EP n'est pas pratique mais a le mérite de présenter les feuillets nécessaires classés (il faudrait un mini-pupitre à roulette pour le poser).

Method ->	**SEBE/SPEAC-based method**
Individual knowledge	25
Collective knowledge	9
Tacit/explicit differentiation	50%

Appendix 24 : Assessment criteria for the test of the SEBE/SPEAC-based method (according to tables 3 A, B and C, Appendix 1)

Experiment reference TEST-IND-ROB-C1 ***FORM 01***
Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method
Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer

Rationale	Comparative evaluation of SEBE methods
Subject(s)	Experienced valve technician: • Gender: male • Age range: 51-60 yo. • Duration in the position: 30 y.
Studied activity	Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer
Procedure applied by the worker(s)	An associated procedure is applied for each case by the subject.
Analyst(s)	PhD researcher / trainer
Method(s)	Work activity analysis: Case 1: SEBE/SPEAC by PhD researcher & self-confrontation by trainer Assessment through the criterion C36 of the 46 criteria-table.
Equipment	LSE subcam for case 1
Timetable/planning	Case 1 (work analysis and assessment): Sept. 2013
Ethics	Informing participant(s) and obtaining informed consent about the research goal, the capture/analysis/validation phases, the anonymous and statistical characters of data use, the use of pictures or videos for illustrative purpose with written agreement of participants.

Experiment reference TEST-IND-ROB-C1 ***FORM 01***
Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method
Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer

A-Preparation phase criteria	Yes/No	Comments / Improvements
A01-Identification of the activity occurrence and of the situation is possible without any difficulty	Y	
A02-Negotiation with the management to carry out the investigation is possible without any difficulty	Y	

NC=Not Concerned

B-Capture phase criteria	Yes/No	Comments / Improvements
B01-Risk analysis researchers/managers is possible without any difficulty	Y	
B02-Installation of external and subjective video devices / framing (less than 10 min.) are possible without any difficulty in time	Y	Check the date and time of the miniaturized camcorder before recording in order to set up correctly the directories and files and facilitate replay.
B03-Capture (subcam and camcorder) of the raw activity (from 15 min. to several hours) is possible without any difficulty	Y	
B04-Storage of material and immediate short feedback / making appointments for the replay interview (less than 10 min.) are possible without any difficulty in time	Y	

NC=Not Concerned

C-Analysis & Conclusion phase criteria	Yes/No	Comments / Improvements ***FORM 01***
Pre-viewing of recordings without participants and selection of particular sequences **C01-is possible without any difficulty** **C02-is not disputed by the participants during replay interview**	 Y Y	 The whole activity was replayed.
C03-Replay interview: Informing participants and obtaining informed consent is possible without any difficulty	Y	
Replay interview with one actor: two first poles of SPEAC model questioning **C04-seems correctly understood by the actor-participant** **C05-gives relevant data according to the researcher's expectation**	 Y/N Y	 Subject cannot answer "What did not you know to do?" For "Having to act", answers very close to the procedure content.
Replay interview with one actor: subjective replay interview **C06-causes actor's spontaneous participation** **C07-gives relevant data according to the researcher's expectation**	 Y Y	
Replay interview with one actor: two last poles of SPEAC model questioning **C08-seems correctly understood by the actor-participant** **C09-gives relevant data according to the researcher's expectation**	 Y Y	 Subject asked questions to make difference with the two first poles. For "Wanting to act", answers referred too much to the prescribed task and therefore were rather similar to answers given for "Having to act".
Replay interview with both actors: two first poles of SPEAC model questioning C10-seems correctly understood by the actors-participants C11-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: subjective replay interview C12-causes actors' spontaneous participation C13-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: two last poles of SPEAC model questioning C14-seems correctly understood by the actors-participants C15-gives relevant data according to the researcher's expectation	 NC NC	
C16-Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection	Y	
Subjects' feelings including the disturbance are discussed in **C17-individual interview** **C18-**collective interview	 Y NC	
Subjects' goals and sub-goals are discussed in **C19-individual interview** **C20-**collective interview	 Y NC	
Subjects' conscious mental representations of the expected results are discussed in **C21-individual interview** C22-collective interview	 Y Y	
C23-Representation of collaborative activity is discussed in collective interview	NC	***FORM 01***

C24-The activity structure is discussed at an individual level and collective level	Y	
Factors of coordination are discussed in **C25-individual interview** C26-collective interview	 Y NC	
Subjects' interactions are discussed in **C27-individual interview** **C28-**collective interview	 Y NC	
Subjects' conscious mental representations of tools are discussed in **C29-individual interview** C30-collective interview	 Y NC	
Post-analysis allows the researcher to analyze/identify C31-subjects' perspective-taking **C32-the studied system distribution** C33-the individual representation of collaborative activity and the consequences for the collective subject C34-subjects' perspective-taking and consequences **C35-the mapping out of the shared knowledge and associated communication vectors** **C36-sets of competencies required for each actor and related explicit and tacit knowledge (individual and collective aspects)**	 NC y NC NC Y Y	 NC, yet subject often gave examples of what could be the action if novice.
C37-Validation (about one hour) is possible without any difficulty in time	Y	
C38-Validation allows researcher and actors to share findings	Y	The exchanges were spontaneous.
C39-Validation helps the researcher to validate/adjust the conclusions	Y	Exchanges helped researcher and trainer to consolidate their findings.
C40-Validation gives the actors a useful feedback	Y	The subject was quite impressed by the knowledge "ask for help" according to the researcher's analysis also named "know to address" according to the trainer.

NC=Not Concerned

Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer

Method ->	**classic self-confrontation**	**SEBE/SPEAC-based method**
Replayed work activity (min)	10	
Individual knowledge	8	14
Collective knowledge	1	3
Tacit/explicit differentiation	No	Yes
Replay interview duration (min.)	30	35
Total time for meeting (min.)	<60	52

Experiment reference TEST-IND-ROB-C2 ***FORM 02***
Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method
Case 2: Setting cams of a valve actuator

Rationale	Comparative evaluation of SEBE methods
Subject(s)	Experienced valve technician: • Gender: male • Age range: 51-60 yo. • Duration in the position: 30 y.
Studied activity	Case 2: Setting cams of a valve actuator
Procedure applied by the worker(s)	An associated procedure is applied for each case by the subject.
Analyst(s)	PhD researcher / trainer
Method(s)	Work activity analysis: Case 2: self-confrontation by trainer & SEBE/SPEAC by PhD researcher Assessment through the criterion C36 of the 46 criteria-table. Observation of case 2 by the outside expert Prof. S. Lahlou and specific contribution for assessment through criteria C04 to C30.
Equipment	AMC subcam for case 2
Timetable/planning	Case 2 (work analysis and assessment): March 2014
Ethics	Informing participant(s) and obtaining informed consent about the research goal, the capture/analysis/validation phases, the anonymous and statistical characters of data use, the use of pictures or videos for illustrative purpose with written agreement of participants.

Experiment reference TEST-IND-ROB-C2 ***FORM 02***

Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method

Case 2: Setting cams of a valve actuator

A-Preparation phase criteria	Yes/No	Comments / Improvements
A01-Identification of the activity occurrence and of the situation is possible without any difficulty	Y	
A02-Negotiation with the management to carry out the investigation is possible without any difficulty	Y	

NC=Not Concerned

B-Capture phase criteria	Yes/No	Comments / Improvements
B01-Risk analysis researchers/managers is possible without any difficulty	Y	
B02-Installation of external and subjective video devices / framing (less than 10 min.) are possible without any difficulty in time	Y	
B03-Capture (subcam and camcorder) of the raw activity (from 15 min. to several hours) is possible without any difficulty	Y	Use large angle lens (asked by the subject) as asked to be checked by the researcher.
B04-Storage of material and immediate short feedback / making appointments for the replay interview (less than 10 min.) are possible without any difficulty in time	Y	

NC=Not Concerned

C-Analysis & Conclusion phase criteria	Yes/No	Comments / Improvements ***FORM 02***
Pre-viewing of recordings without participants and selection of particular sequences **C01-is possible without any difficulty** **C02-is not disputed by the participants during replay interview**	 Y Y	 The whole activity was replayed.
C03-Replay interview: Informing participants and obtaining informed consent is possible without any difficulty	Y	Prof. Lahlou asked to emphasize the help provided by the subject to the researcher.
Replay interview with one actor: two first poles of SPEAC model questioning **C04-seems correctly understood by the actor-participant** **C05-gives relevant data according to the researcher's expectation**	 Y/N Y	Be careful with tenses of the verbs. Subject could not answer "What did not you know to do?" For "Having to act", answers very close to the procedure content.
Replay interview with one actor: subjective replay interview **C06-causes actor's spontaneous participation** **C07-gives relevant data according to the researcher's expectation**	 Y Y	
Replay interview with one actor: two last poles of SPEAC model questioning **C08-seems correctly understood by the actor-participant** **C09-gives relevant data according to the researcher's expectation**	 Y Y	 Subject asked questions to make difference with the two first poles. For "Wanting to act", answers referred too much to the prescribed task (as in case 1) and yet here answers were different from those given for "Having to act".
Replay interview with both actors: two first poles of SPEAC model questioning C10-seems correctly understood by the actors-participants C11-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: subjective replay interview C12-causes actors' spontaneous participation C13-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: two last poles of SPEAC model questioning C14-seems correctly understood by the actors-participants C15-gives relevant data according to the researcher's expectation	 NC NC	
C16-Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection	Y/N	Yes according to the PhD researcher, but not enough to Prof. Lahlou.
Subjects' feelings including the disturbance are discussed in **C17-individual interview** **C18-**collective interview	 Y NC	
Subjects' goals and sub-goals are discussed in **C19-individual interview** **C20-**collective interview	 Y/N NC	 Yes according to the PhD researcher, but not enough to Prof. Lahlou.
Subjects' conscious mental representations of the expected results are discussed in **C21-individual interview** C22-collective interview	 Y Y	***FORM 02***

C23-Representation of collaborative activity is discussed in collective interview	NC	
C24-The activity structure is discussed at an individual level and collective level	Y	
Factors of coordination are discussed in **C25-individual interview** C26-collective interview	 Y NC	
Subjects' interactions are discussed in **C27-individual interview** **C28-**collective interview	 Y NC	
Subjects' conscious mental representations of tools are discussed in **C29-individual interview** C30-collective interview	 Y NC	
Post-analysis allows the researcher to analyze/identify C31-subjects' perspective-taking **C32-the studied system distribution** C33-the individual representation of collaborative activity and the consequences for the collective subject C34-subjects' perspective-taking and consequences **C35-the mapping out of the shared knowledge and associated communication vectors** **C36-sets of competencies required for each actor and related explicit and tacit knowledge (individual and collective aspects)**	 NC Y Y Y Y Y	 NC, yet subject often gave examples of what could be the action if novice.
C37-Validation (about one hour) is possible without any difficulty in time	Y	
C38-Validation allows researcher and actors to share findings	Y	
C39-Validation helps the researcher to validate/adjust the conclusions	Y	
C40-Validation gives the actors a useful feedback	Y	

NC=Not Concerned

Experiment reference TEST-IND-ROB-C2 — *EFFICIENCY*
Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method — *FORM 02*
Case 2: Setting cams of a valve actuator

Method ->	**classic self-confrontation**	**SEBE/SPEAC-based method**
Replayed work activity (min)	About 10	
Individual knowledge	11	16
Collective knowledge	2	6
Tacit/explicit differentiation	N	Y
Replay interview duration (min.)	40	38
Total time for meeting (min.)	80	76

Rationale	Testing the SEBE/SPEAC-based method on pilot's individual activity
Subject(s)	Experienced pilot: • Gender: male • Age range: 21-30 yo. • Duration in the position: 5 y.
Studied activity	Block watch-around
Procedure applied by the worker(s)	No procedure.
Analyst(s)	PhD researcher
Timetable/planning	Dec. 2013
Method(s)	Work activity analysis: SEBE/SPEAC-based method. Assessment through the 46 criteria-table.
Equipment	LSE subcam
Ethics	Informing participant(s) and obtaining informed consent about the research goal, the capture/analysis/validation phases, the anonymous and statistical characters of data use, the use of pictures or videos for illustrative purpose with written agreement of participants.

Experiment reference TEST-IND-OP-C0 ***FORM 03***

Assessment of the of the SEBE/SPEAC-based method (46 criteria) on pilot's activity

A-Preparation phase criteria	Yes/No	Comments / Improvements
A01-Identification of the activity occurrence and of the situation is possible without any difficulty	Y	
A02-Negotiation with the management to carry out the investigation is possible without any difficulty	Y	

NC=Not Concerned

B-Capture phase criteria	Yes/No	Comments / Improvements
B01-Risk analysis researchers/managers is possible without any difficulty	Y	
B02-Installation of external and subjective video devices / framing (less than 10 min.) are possible without any difficulty in time	Y	Check the date and time of the miniaturized camcorder before recording in accordance with the time of the simulator video system.
B03-Capture (subcam and camcorder) of the raw activity (from 15 min. to several hours) is possible without any difficulty	Y	Be careful about audio recording.
B04-Storage of material and immediate short feedback / making appointments for the replay interview (less than 10 min.) are possible without any difficulty in time	Y	The appointment was announced, but could not be scheduled at the moment. Due to job constrains on both sides, it was done by phone a few days later.

NC=Not Concerned

C-Analysis & Conclusion phase criteria	Yes/No	Comments / Improvements ***FORM 03***
Pre-viewing of recordings without participants and selection of particular sequences **C01-is possible without any difficulty** **C02-is not disputed by the participants during replay interview**	 Y Y	 The beginning of the activity was replayed.
C03-Replay interview: Informing participants and obtaining informed consent is possible without any difficulty	Y	
Replay interview with one actor: two first poles of SPEAC model questioning **C04-seems correctly understood by the actor-participant** **C05-gives relevant data according to the researcher's expectation**	 Y/N Y	 "Not Having to act" produces ignoring "absurd way to do".
Replay interview with one actor: subjective replay interview **C06-causes actor's spontaneous participation** **C07-gives relevant data according to the researcher's expectation**	 Y Y	
Replay interview with one actor: two last poles of SPEAC model questioning **C08-seems correctly understood by the actor-participant** **C09-gives relevant data according to the researcher's expectation**	 Y Y	 "Having to act" and "Knowing to act" complete each other.
Replay interview with both actors: two first poles of SPEAC model questioning C10-seems correctly understood by the actors-participants C11-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: subjective replay interview C12-causes actors' spontaneous participation C13-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: two last poles of SPEAC model questioning C14-seems correctly understood by the actors-participants C15-gives relevant data according to the researcher's expectation	 NC NC	
C16-Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection	Y	
Subjects' feelings including the disturbance are discussed in **C17-individual interview** **C18-**collective interview	 Y NC	
Subjects' goals and sub-goals are discussed in **C19-individual interview** **C20-**collective interview	 Y NC	
Subjects' conscious mental representations of the expected results are discussed in **C21-individual interview** C22-collective interview	 Y Y	
C23-Representation of collaborative activity is discussed in collective interview	NC	***FORM 03***
C24-The activity structure is discussed at an individual level and collective level	Y	

Factors of coordination are discussed in **C25-individual interview** C26-collective interview	 Y NC	
Subjects' interactions are discussed in **C27-individual interview** **C28-**collective interview	 Y NC	
Subjects' conscious mental representations of tools are discussed in **C29-individual interview** C30-collective interview	 Y NC	
Post-analysis allows the researcher to analyze/identify C31-subjects' perspective-taking **C32-the studied system distribution** C33-the individual representation of collaborative activity and the consequences for the collective subject C34-subjects' perspective-taking and consequences **C35-the mapping out of the shared knowledge and associated communication vectors** **C36-sets of competencies required for each actor and related explicit and tacit knowledge (individual and collective aspects)**	 NC Y NC NC Y Y	
C37-Validation (about one hour) is possible without any difficulty in time	Y	Be careful about audio recording.
C38-Validation allows researcher and actors to share findings	Y	Exchanges were spontaneous.
C39-Validation helps the researcher to validate/adjust the conclusions	Y	Audio track of the replay interview recording (obtained with LSE device) is spoiled despite cautions. However, notes were relevant.
C40-Validation gives the actors a useful feedback	Y	Positive feeling after the replay interview

NC=Not Concerned

Method ->	**SEBE/SPEAC-based method**
Replayed work activity (min)	4
Individual knowledge	13
Collective knowledge	1
Tacit/explicit differentiation	Y
Replay interview duration (min.)	20
Total time for meeting (min.)	45

Rationale	Testing the SEBE/SPEAC-based method on field worker's individual activity
Subject(s)	Experienced field worker: • Gender: male • Age range: 21-30 yo. • Duration in the position: 4.5 y.
Studied activity	Isolating steam generator #1 due to high level of radioactivity inside.
Procedure applied by the worker(s)	Procedure RFLL027.
Analyst(s)	PhD researcher
Timetable/planning	Dec. 2013
Method(s)	Work activity analysis: SEBE/SPEAC-based method. Assessment through the 46 criteria-table.
Equipment	LSE subcam
Ethics	Informing participant(s) and obtaining informed consent about the research goal, the capture/analysis/validation phases, the anonymous and statistical characters of data use, the use of pictures or videos for illustrative purpose with written agreement of participants.

Experiment reference TEST-IND-AGT-C0 ***FORM 04***

Assessment of the of the SEBE/SPEAC-based method (46 criteria) on pilot's activity

A-Preparation phase criteria	Yes/No	Comments / Improvements
A01-Identification of the activity occurrence and of the situation is possible without any difficulty	Y	
A02-Negotiation with the management to carry out the investigation is possible without any difficulty	Y	

NC=Not Concerned

B-Capture phase criteria	Yes/No	Comments / Improvements
B01-Risk analysis researchers/managers is possible without any difficulty	Y	
B02-Installation of external and subjective video devices / framing (less than 10 min.) are possible without any difficulty in time	Y	Check the date and time of the miniaturized camcorder before recording in accordance with the time of the simulator video system.
B03-Capture (subcam and camcorder) of the raw activity (from 15 min. to several hours) is possible without any difficulty	Y	Be careful about audio recording.
B04-Storage of material and immediate short feedback / making appointments for the replay interview (less than 10 min.) are possible without any difficulty in time	Y	The appointment was announced, but could not be scheduled at the moment. Due to job constrains on both sides, it was done by phone a few days later.

NC=Not Concerned

C-Analysis & Conclusion phase criteria	Yes/No	Comments / Improvements ***FORM 04***
Pre-viewing of recordings without participants and selection of particular sequences **C01-is possible without any difficulty** **C02-is not disputed by the participants during replay interview**	 Y Y	 The beginning of the activity was replayed from leaving the technicians room to finding the first valve: it makes sense for the subject.
C03-Replay interview: Informing participants and obtaining informed consent is possible without any difficulty	Y	
Replay interview with one actor: two first poles of SPEAC model questioning **C04-seems correctly understood by the actor-participant** **C05-gives relevant data according to the researcher's expectation**	 Y/N Y	 For "Having to act", answers very close to the procedure content.
Replay interview with one actor: subjective replay interview **C06-causes actor's spontaneous participation** **C07-gives relevant data according to the researcher's expectation**	 Y Y	
Replay interview with one actor: two last poles of SPEAC model questioning **C08-seems correctly understood by the actor-participant** **C09-gives relevant data according to the researcher's expectation**	 Y Y	 A conflict appeared between poles "Having to act" and "Wanting to act".
Replay interview with both actors: two first poles of SPEAC model questioning C10-seems correctly understood by the actors-participants C11-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: subjective replay interview C12-causes actors' spontaneous participation C13-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: two last poles of SPEAC model questioning C14-seems correctly understood by the actors-participants C15-gives relevant data according to the researcher's expectation	 NC NC	
C16-Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection	Y	
Subjects' feelings including the disturbance are discussed in **C17-individual interview** **C18-**collective interview	 Y NC	
Subjects' goals and sub-goals are discussed in **C19-individual interview** **C20-**collective interview	 Y NC	
Subjects' conscious mental representations of the expected results are discussed in **C21-individual interview** C22-collective interview	 Y Y	
C23-Representation of collaborative activity is discussed in collective interview	NC	***FORM 04***

C24-The activity structure is discussed at an individual level and collective level	Y	
Factors of coordination are discussed in **C25-individual interview** C26-collective interview	 Y NC	
Subjects' interactions are discussed in **C27-individual interview** **C28**-collective interview	 Y NC	
Subjects' conscious mental representations of tools are discussed in **C29-individual interview** C30-collective interview	 Y NC	
Post-analysis allows the researcher to analyze/identify C31-subjects' perspective-taking **C32-the studied system distribution** C33-the individual representation of collaborative activity and the consequences for the collective subject C34-subjects' perspective-taking and consequences **C35-the mapping out of the shared knowledge and associated communication vectors** **C36-sets of competencies required for each actor and related explicit and tacit knowledge (individual and collective aspects)**	 NC Y NC NC Y Y	 There may be indirect representations.
C37-Validation (about one hour) is possible without any difficulty in time	Y	
C38-Validation allows researcher and actors to share findings	Y	Exchanges were spontaneous.
C39-Validation helps the researcher to validate/adjust the conclusions	Y	
C40-Validation gives the actors a useful feedback	Y	

NC=Not Concerned

Method ->	SEBE/SPEAC-based method
Replayed work activity (min)	11
Individual knowledge	17
Collective knowledge	10
Tacit/explicit differentiation	Y
Replay interview duration (min.)	30
Total time for meeting (min.)	45

Experiment reference TEST-COLL-OP-AGT 01 (collaborative activity) ***FORM 05***
Assessment of the of the SEBE/SPEAC-based method (46 criteria) on collaborative activity

A-Preparation phase criteria	Yes/No	Comments / Improvements
A01-Identification of the activity occurrence and of the situation is possible without any difficulty	Y	Simulation situation was designed for this purpose.
A02-Negotiation with the management to carry out the investigation is possible without any difficulty	Y	Simulation situation was designed for this purpose.

NC=Not Concerned

B-Capture phase criteria	Yes/No	Comments / Improvements
B01-Risk analysis researchers/managers is possible without any difficulty	Y	Simulation situation was designed for this purpose.
B02-Installation of external and subjective video devices / framing (less than 10 min.) are possible without any difficulty in time	Y	Check the date and time of the miniaturized camcorder before recording in accordance with the time of the simulator video system.
B03-Capture (subcam and camcorder) of the raw activity (from 15 min. to several hours) is possible without any difficulty	Y	
B04-Storage of material and immediate short feedback / making appointments for the replay interview (less than 10 min.) are possible without any difficulty in time	Y	

NC=Not Concerned

C-Analysis & Conclusion phase criteria	Yes/No	Comments / Improvements ***FORM 05***
Pre-viewing of recordings without participants and selection of particular sequences **C01-is possible without any difficulty** **C02-is not disputed by the participants during replay interview**	 Y Y	 Due to the length of the video recordings (about 1h each), a selection of sequences was done.
C03-Replay interview: Informing participants and obtaining informed consent is possible without any difficulty	Y	
Replay interview with one actor: two first poles of SPEAC model questioning **C04-seems correctly understood by the actor-participant** **C05-gives relevant data according to the researcher's expectation**	 Y Y	 Subject was not disturbed by direct questions about the poles.
Replay interview with one actor: subjective replay interview **C06-causes actor's spontaneous participation** **C07-gives relevant data according to the researcher's expectation**	 Y Y	
Replay interview with one actor: two last poles of SPEAC model questioning **C08-seems correctly understood by the actor-participant** **C09-gives relevant data according to the researcher's expectation**	 Y Y	 Subject was not disturbed by direct questions about the poles.
Replay interview with both actors: two first poles of SPEAC model questioning C10-seems correctly understood by the actors-participants C11-gives relevant data according to the researcher's expectation	 NC NC	
Replay interview with both actors: subjective replay interview C12-causes actors' spontaneous participation C13-gives relevant data according to the researcher's expectation	 Y Y	
Replay interview with both actors: two last poles of SPEAC model questioning C14-seems correctly understood by the actors-participants C15-gives relevant data according to the researcher's expectation	 NC NC	
C16-Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection	Y	
Subjects' feelings including the disturbance are discussed in **C17-individual interview** **C18-**collective interview	 Y Y	Involving several subjects in the same activity helps to work this point.
Subjects' goals and sub-goals are discussed in **C19-individual interview** **C20-**collective interview	 Y Y	
Subjects' conscious mental representations of the expected results are discussed in **C21-individual interview** C22-collective interview	 Y Y	
C23-Representation of collaborative activity is discussed in collective interview	Y	Involving several subjects in the same activity helps to work this point.
C24-The activity structure is discussed at an individual level and collective level	Y	***FORM 05***

Factors of coordination are discussed in **C25-individual interview** C26-collective interview	 Y Y	Involving several subjects in the same activity helps to work this point.
Subjects' interactions are discussed in **C27-individual interview** **C28-**collective interview	 Y Y	Involving several subjects in the same activity helps to work this point.
Subjects' conscious mental representations of tools are discussed in **C29-individual interview** C30-collective interview	 Y Y	
Post-analysis allows the researcher to analyze/identify C31-subjects' perspective-taking **C32-the studied system distribution** C33-the individual representation of collaborative activity and the consequences for the collective subject C34-subjects' perspective-taking and consequences **C35-the mapping out of the shared knowledge and associated communication vectors** **C36-sets of competencies required for each actor and related explicit and tacit knowledge (individual and collective aspects)**	 Y Y Y Y Y Y	 Involving several subjects in the same activity helps to work this point. Involving several subjects in the same activity helps to work this point. Involving several subjects in the same activity helps to work this point.
C37-Validation (about one hour) is possible without any difficulty in time	Y	
C38-Validation allows researcher and actors to share findings	Y	
C39-Validation helps the researcher to validate/adjust the conclusions	Y	
C40-Validation gives the actors a useful feedback	Y	

NC=Not Concerned

field worker's activity.

Method ->	**Individual replay interview SEBE/SPEAC-based method**
Replayed work activity (min)	8
Individual knowledge	27
Collective knowledge	13
Tacit/explicit differentiation	Y
Replay interview duration (min.)	30
Total time for meeting (min.)	60

pilot's activity.

Method ->	**Individual replay interview SEBE/SPEAC-based method**
Replayed work activity (min)	12
Individual knowledge	15
Collective knowledge	8
Tacit/explicit differentiation	N
Replay interview duration (min.)	42
Total time for meeting (min.)	60

Appendix 25 : Detailed results of the experimental test segment of the SEBE/SPEAC protocol

Experiment reference TEST-IND-ROB-C1
Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method
Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer
Associated assessment table: FORM 01 (in appendix 24)

The neutral point set up consists in adjusting the movement of the mobile pieces of the device to electrical input signal with reference to a given position. During the activity, the intervener has several manipulations of the device to do, several position measurements to perform, calculations to do and must find the matching of some device parts. The subjective movie watched in replay interview was a 10 min. video and covered the whole activity.

Reference: Rob 2013 09\activity, fichier 445 Mo

The following paragraphs assess the SEBE/SPEAC-based replay interview according to criteria table 3.

Tables 3 A, B is giving the assessment criteria for the Preparation phase and the Capture phase resp. of the SEBE/SPEAC-based method. All of them were met. No difficulty was encountered. In terms of improvement, a recommendation regarding date and time set up of the miniaturized camcorder was done in order to facilitate the replay (see Appendix 24: Assessment criteria for the test of the SEBE/SPEAC-based method, FORM 01).

Table 3 C is giving the assessment criteria for the Analysis and Conclusions phase of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing this phase. Of course it integrates a bias due to the subjectivity of the researcher and the difficulty of the researcher to stand distanced from the analysis whilst being actor of it. Yet this bias is removed in case 2 by the contribution of an outside expert. Some of the criteria gave rise to comments that are discussed here.

C04- Replay interview: two first poles of SPEAC model questioning seems correctly understood by the subject

Questioning the pole "Having to act" of the SPEAK model made the subject remaining very close to the procedure related to the task. The subject did not give more information than those available in the procedure.

The valve technician answering the question "What did not you know to do?" said:

Fragment 1

(Subject) S: What I don't know to do? (09.0) What I don't know to do? (02.0) I don't know (.) to (05.0)

The technician opened his hands and the researcher asked:

(Researcher) R: You don't see?

S: Uh:::: (03.0) No I don't see.

Reference file: Data subcam et al\Rob 2013 09\IR (LSE) File 01 / 05:25

C06- Replay interview: subjective replay interview causes subject's spontaneous participation

The subject showed spontaneous participation during the interview replay. Very soon, he pressed the space bar of the computer keyboard to stop the replay and to take time to make comments about what was going on (see Fig. 29).

C09- Replay interview: two last poles of SPEAC model questioning gives relevant data

Answers to the question "What did you want to do?" questioning the pole "Wanting to act" referred too much to the prescribed task and therefore were rather similar to the answer given to the question "What did you had to do?" questioning the pole "Having to act".

C31- Post-analysis allows the researcher to analyze/identify subjects' perspective-taking

Subject's perspective-taking is based on the view of the co-worker subjective film and thus is worked out when analyzing collaborative activity with two co-workers. Yet, during the replay interview, the subject often gave examples of what could be the action if the task would be performed by a novice.

C35- Post-analysis allows the researcher to analyze/identify the mapping out of the shared knowledge and associated communication vectors

The mapping out of the shared knowledge and associated communication vectors was facilitated by what is written above regarding C31.

C40-Validation gives the actors a useful feedback

After the replay interview with the researcher, the valve technician insisted to give his feeling about the subjective video and accepted to be recorded. Here follows an excerpt of the transcription of this exchange: "tomorrow, it is something [the video] I want to present to my trainees. [...] I think that the person, when he will have seen that and perform the act, will think about how he can do not to be in the mess [...] It is good to watch the gesture." The worker left the researcher's office with a copy of the video and the week after, he was using it to train novices. The valve technician was also quite impressed by the knowledge "ask for help" according to the researcher's analysis also named "know to address" according to the trainer. It was presented as a tacit knowledge and indeed, the subject seemed doubtful about it. But after one week, while meeting in corridors, he explained to the analysts that he had discovered through the SEBE how important this knowledge could be.

Reference file: Data subcam et al\Rob 2013 09\actor'sfeeling vs IR

From the 10 minutes subjective video recording of the work activity, two kinds of replay interviews were conducted with the subject performing the task:

- a SEBE/SPEAC-based replay interview by PhD researcher,
- a self-confrontation replay interview by an experienced trainer.

These two kinds of replay interviews were carried out in order to compare their performance with regard to the final goal: accessing to the knowledge that makes competencies of the worker.

Characteristics of the analysts (PhD researcher and trainer) are given in table 9.

Table 9: Characteristics of the analysts for comparison of replay interviews.

Features	PhD researcher	Trainer
Current job	Researcher	Trainer
Duration of current job (y)	5	2.5
Previous job	Researcher	Reactor pilot
Duration of previous job (y)	23	13
Academic level	Level A + 8	Level A + 2
Gender / Age range (y)	Male / 41-50	Male / 41-50

Both replay interviews were video recorded and then analyzed.

PhD researcher's replay interview

For the SEBE/SPEAC-based method, the three phases constituting the replay interview lasted altogether 52 minutes; self-confrontation took 35 minutes.

The researcher was positioned facing the subject, and the screen was positioned on the side between the two: it was the subject who led the reading of the video (play/stop/replay) as suggested by the researcher at the beginning of the interview (Fig. 29).

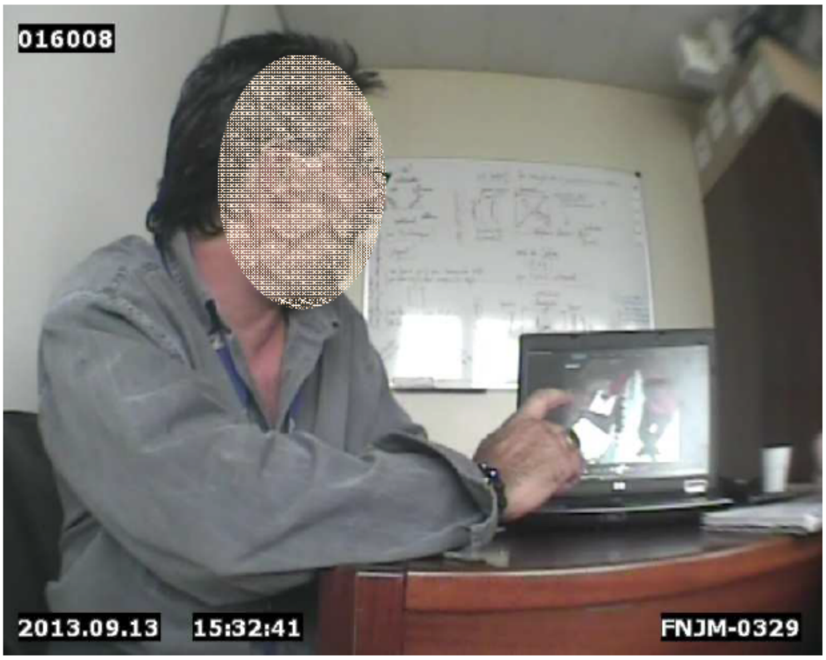

Fig. 29: Excerpt of the SEBE/SPEAC-based replay interview showing the valve technician in experimental case #1: on the picture, the subject rises his finger to press the space bar of the computer keyboard in order to stop the replay video and make a comment.
Reference video : Rob 2013 09\IR (LSE) fichier 1Go t=10:39

The comparative performance assessment of the methods was based on their capacity to identify knowledge which is necessary for a novice worker to be trained in order to perform the studied task.
The researcher's analysis provided the results in table 10, where knowledge and know-how identified as potentially tacit are highlighted in yellow. The researcher proceeded by categorizing necessary fields of competencies for which he identified knowledge; comparing what was said spontaneously by the subject before the replay interview (questioning the two first poles of the SPEAC model) and during self-confrontation, with what was resulting from a deepened questioning and from the questioning of the last two poles of the SPEAC (questioning the two last poles of the SPEAC model), tacit knowledge was identified.

Table 10: Matrix using the SEBE/SPEAC-based method for activity "Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer"

Individual level of the activity						
Fields of competencies	Prepare the intervention before performing	Identify the different constitutive parts of the equipment and know the operating	Use a MO with its various parts to fill in	Implement methods reducing uncertainty of measurement	Implement methods reducing probability of error calculation	Re-qualify
Knowledge & associated Know-How	-being aware of sides alignments to establish his toolbox with the good ruler and the magnet used to align the sides - being aware of the necessity to get easily the tools to put the tools on the work desk -reading MO to anticipate the chronology of the operations	-knowing the nomenclature and the associated parts of the equipment to identify them in the field -knowing that available air facilitates certain maneuvers to not be stop in the test process -understanding what a neutral point is to understand the MO	-reading and understanding what is asked to be able to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality	-knowing the length to measure to use a suitable size for the ruler -being aware of sides alignments to use a block or a magnet to align reading points	-being aware of possible calculation errors to apply a protocol reducing it: use an independent sheet for the dimensions survey -being aware of possible calculation errors to avoid rush: take time to write dimensions at the end of MO by repeating the calculations	-understanding the requalification issue to guarantee their consistency -knowing details not said in the MO to make the quality of requalification (eg: the absence of foreign body on the rollers, carving the spoon)
Collective level of the activity						
Fields of competencies	Implement / accept the cross control of measurements / calculations	Operate the valve during measurement of dimensions when requalification	Make the shift team efficient			
Knowledge	-knowing the benefit of cross control in order to ask for it	-asking the right person for help	-being aware of what will the document serve to fill it in clearly for the next user (shift teams)			

Trainer's replay interview

The trainer's replay interview was based on a classic self-confrontation relying on a trainer's training regarding Explicitation Techniques according to the school of Vermerch (1994) and on his professional experience of two and a half years as a simulator trainer involving almost daily sessions of simulation debriefing. The structure of his replay interview held in three phases:

- Prior questioning of the subject: questions of understanding the activity especially for a novice (the trainer had viewed the video of the activity just before).
- Viewing the video by the trainer and the subject: the subject was asked to explain what he did; trainer's questioning on how to do the activity to identify what the subject was implementing to carry out such action.
- Posterior questioning to the viewing: to find out how the subject reached his level of competencies.

Only the second phase was timed and lasted 30 min. However they did not spend together more than one hour in the office for interview.

The trainer was positioned facing the screen, and the actor was sat beside the trainer: it was the trainer who led the reading of the video (play/stop/replay) (Fig. 30).

Fig. 30: Excerpt of the classic self-confrontation replay interview showing the valve technician movie in experimental case #1: on the picture, the trainer (left) and the technician are watching the computer screen located in front of the trainer.

Reference video : Rob 2013 09\IR (UFPI) fichier 34Mo t=00:41

The trainer's analysis provided the results in table 11, where knowledge and know-how identified as tacit is not pointed out as the trainer did not had any criteria to identify them.

Table 11: Knowledge and know-how identified using the classic self-confrontation method for activity "Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer"

Individual level of the activity	
Knowledge	-read and understand MO -have the required knowledge for a valve technician - know to break down a complex task in elementary activities -know go beyond ownership of MO (Métis: use the white sheet) - know to prepare activity -namely reduce the sources of error and uncertainty -know requalification -know to control
Collective level of the activity	
Knowledge	-know to address colleagues (request for assistance)

The criteria assessed for performance are summarized in table 12. Results show a better efficiency for the SEBE/SPEAC method since:

- the number of items identified at an individual as well as at a collective level are greater,
- immediate identification of tacit knowledge is possible with the SEBE/SPEAC-based method only,
- duration of meeting and interview is similar for both methods.

Table 12: Criteria assessed for performance "Case 1: Setting a neutral point on a pneumatic actuator SEREG simple membrane without reducer".

Method ->	classic self-confrontation	SEBE/SPEAC-based method
Replayed work activity (min)	10	
Individual knowledge	8	14
Collective knowledge	1	3
Tacit/explicit differentiation	No	29.4%
Replay interview duration (min.)	30	35
Total time for meeting (min.)	<60	52

A feedback was then made collectively to the valve technician by the researcher and the trainer in order to validate or not through discussion the results of analyses and to provide eventually beneficial advice to the subject.

Limits of these first results lie in:

- The aforementioned primacy effect (SPEAC method then classic method) then favoring the second replay interview: this possible bias will be removed in experimental case 2; hence claiming that the SEBE/SPEAC-based method is more efficient is pending.
- The absence of comparison with methods actually implemented within the professional training strategy of the company (namely the SAT method described in beginning of section II-2-1).

Conclusion and relevant points of these first results are:

- The subject was spontaneous in participating to the recording session and to the replay interview.
- The main goal of the experiment was to access to what make the competencies of workers. This goal was reached if referring to the first comparison done with another method of replay interview.
- We may have difficulties in obtaining relevant information when using direct questions regarding the poles of the SPEAC model (C04-C09).
- Perspective-taking may be worked out by asking the subject what he would do if he would be novice.
- Subjective video may become a pedagogical tool used by experienced worked to train novices.
- Subject had a positive feeling after the replay interview (C40) and was enthusiastic by the experiment.

Experiment reference TEST-IND-ROB-C2
Comparative evaluation of the SEBE/SPEAC-based method vs the self-confrontation method
Case 2: Setting cams of a valve actuator
Associated assessment table: FORM 02 (in appendix 24)

Setting cams consists in adjusting position of pieces located in the upper box of the device. During the activity, the intervener has several manipulations of the device to do, several position measurements to perform and must find the matching of some device parts.

The subjective movie watched in replay interview was a 10 min. video and covered the whole activity.

Reference: Rob 2013 12\activity, fichier 545 Mo

Tables 3 A, B, assessment criteria for the Preparation phase and the Capture phase resp. of the SEBE/SPEAC-based method, were rated after performing each of these phases by the PhD researcher and an outside expert, Prof. Lahlou who attended all phases.

As for case 1, all of these first criteria were met. No difficulty was encountered (see Appendix 24: Assessment criteria for the test of the SEBE/SPEAC-based method, FORM 02) but a large angle lens may improve the subjective view and the light improvement may be useful (B03).

Table 3 C is giving the assessment criteria for the Analysis and Conclusion phase of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing this phase on the basis of a critical feedback of the qualified expert, Prof. Lalhou. Here, the bias due to the subjectivity of the PhD researcher and the difficulty of the researcher to stand distanced from the analysis whilst being actor of it was compensated by the qualified expert's point of view. Some of the criteria gave rise to comments that are discussed thereafter.

C03-Replay interview: Informing participants and obtaining informed consent is possible

Prof. Lahlou asked to emphasize the help provided by the subject to the researcher. This helps for the subject to make sense about what he is about to undertake with the researcher.

C04/C09: Replay interview: two first poles of SPEAC model questioning seems correctly understood by the actor-participant / Replay interview: two last poles of SPEAC model questioning gives relevant data

Be careful about the tense of verb used. Listening to the audio recording of the replay interview, it appeared that the appropriate tense was the questioning of the tow first poles of the SPEAC model is the present. This help the subject to think and answer as if he was about to perform the task, which is the sought effect. The appropriate tense for the last poles is the preterit, because it helps the subject to recall what he did, what he just viewed during the self-confrontation, which is also the sought effect.

C04/C05: Replay interview: two first poles of SPEAC model questioning seems correctly understood by the actor-participant / Replay interview: two first poles of SPEAC model questioning gives relevant data

The subject had some difficulties to answer questioning Not Having to do.

Reference file: Data subcam et al\Rob 2013 12\IR (LSE) File 711_0017 (t=12:10)

Fragment 2

Researcher (R):	what did not you had to do?
Subject (S):	What I did not have to do? (06.5) What I did not [have to do.
R:	[The question is what you did not had to do and you did not do, or that you knew you did not have to do, or you did but you did not have to do, this is the question=
S:	=Huhu=
R:	=It may be nothing! (04.6)
S:	What I (.) I don't see, no. I don't see what I did not had to do. (t=12:46)

When he was asked "What you did not know to do?" he answered after a pause of 6.5 seconds: "I don't know. I don't see what I did not know to do" and then immediately followed by a mixed: "what I did not had to do" with a silent pause of 11.4 seconds after, broken by the researcher. This answer is not satisfactory and shows that the question is blocking the subject likely by summoning directly a memory effort (Vermersch, 1994: 126). During the feedback of this interview, Prof. Lahlou suggested to use indirect and multiple questions to replace each direct question.

C05- Replay interview: two first poles of SPEAC model questioning gives relevant data

Again when answering question about *Having to act*, the subject stayed close to the procedure.

C09- Replay interview: two last poles of SPEAC model questioning gives relevant data

when questioning *Wanting to act*, answer were referring to the prescribed task as for the questioning of *Having to act*. Yet the contents of answers differed indeed. For *Having to act*, we obtained: setting up the cam of the actuator, stopping at the right position when opening or closing and in addition with adequate light transmission. Requalifying with success. For *Waning to act*, we obtained: setting up the actuator, identifying the serial numbers of engines.

C16/C19: Replay interviews: the consecutive verbalizations give effectively actors' expressed goals objectified in the data collection / Subjects' goals and sub-goals are discussed in individual interview

Prof. Lahlou felt that the questions asked by the PhD researcher in the aim of identifying goals and sub-goals were not enough numerous and not enough frequent. This was said for the replay interview as well as for the introduction of the meeting.

C31- Post-analysis allows the researcher to analyze/identify subjects' perspective-taking

The subject had the same concerns regarding novice colleagues than in case 1 (he gave spontaneously examples of what could be the action if performed by a novice) and this made him worked the perspective-taking.

One of the items addressed spontaneously by the subject, when questioning the pole Not Wanting to do, was related to what a novice must avoid:

Reference file: Data subcam et al\Rob 2013 12\IR (LSE) File 711_0017 (t=13:55)

Fragment 3

Subject (S):	Then if you put yourself in the skin of a <u>novice</u>(.) there are a lot of things not to be done. (13.84)
Researcher(R):	You can give me an <u>example</u>?
S:	Yes(.) Controlling the:: <u>switches</u> when operating on the bound(.) with the finger(.) this must never be done.

Then followed an exchange to explain what is 'controlling the switch'.

Reference file: Data subcam et al\Rob 2013 12\IR (LSE) File 711_0017 (t=14:50)

Fragment 4

S:	You might get crush your finger by a cam(.) <u>Here</u> there is a mechanical risk, yeah=
R:	=So you put yourself in the body of a <u>novice</u> and you tell me you absolutely must not do that?=
S:	=Yes(.) this I must not do it=
R:	=Ok. I am an <u>experienced</u> worker(.) I can <u>do</u> it?! According to [what you told me.
S:	[<u>Oh no</u>!
R:	So? (.) Why when I ask you 'what you must not do?' you don't tell me that you too must not do it!
S:	I must not do it either!=
R:	=Yes. You are concerned?
S:	Yes but I (.) Yes! I must not do it either! Yes!
R:	And why you don't tell me that it is something you must not do? (01.0)
S:	[laughs=02.46] I shall take another chocolate! [laughs] Because it is so logical!"

Prof. Lahlou noticed here that the interviewed subject's perspective-taking of a novice worker could be one of the ways to find devious questions regarding the pole *Wanting to act* as well as *Having to act*.

C40-Validation gives the actors a useful feedback

Subject had again a positive feeling after the replay interview and was enthusiastic about the experiment.

From the 10 minutes subjective video recording of the work activity, the two kinds of replay interviews were conducted with the subject performing the task by the same analysts (characteristics in table 9) with two differences beyond changing the work activity:

- the SEBE/SPEAC-based replay interview was conducted after the classic self-confrontation method,
- the SEBE/SPEAC-based replay interview was conducted by the PhD researcher under the outside expert's observation; this did not disturb the PhD researcher.

Conditions and analysts' characteristics to perform these replay interviews case #2 are exactly the same than for case #1 (see table 9).

PhD researcher's replay interview

Table 13 gives the fields of competencies and related knowledge and know-how identified by the replay interview analysis.

Table 13: Matrix identified using the SEBE/SPEAC-based method for activity "Case 2: Setting cams of a valve actuator"

Individual level of the activity						
Fields of competencies	Prepare the intervention before performing	Identify the different constitutive parts of the equipment and know the operating	Use a MO with its various parts to fill in	Implement methods reducing risks of injures or damages	Implement methods reducing probability of losing pieces	Re-qualify
Knowledge	- knowing that MO does not specify tools needed to establish the toolbox with a large panel of instruments -being aware of the benefit of a magnet to put on the steer wheel to help counting the revolutions -read MO to anticipate the actions -having a mental representation of the forthcoming situation to identify security and safety potential risks	-knowing the nomenclature and the associated parts of the equipment to make a link between them -knowing the meaning of some sounds related to certain maneuvers -being conscious of the benefits of hearing and feeling equipment and tools to interpret it -understanding what a cam and its bound are to be efficient	-reading and understanding what is asked to be able to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality	-know which place or operation to avoid with the fingers - use appropriate gloves -know where/when cables might be snatched.	-know to collect the piece in a safe place (use the drop-down maid or put the pieces in the hood)	-having been told about a set-up specificities to know how to control a set-up. -understanding the requalification issue to guarantee their consistency -knowing details not said in the MO to make the quality of requalification (some details may be feel with the finger on equipment or tools, others may be seized with the eye)
Collective level of the activity						
Fields of competencies	Adapt the collaborative work	Use co-workers' competencies				
Knowledge	-know how to cope with the impossible use of the phone while a co-worker will stay in another room to check appearance of lights -coordinate actions of co-workers -have an operational communication of quality (understandable by co-workers)	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do				

Trainer's replay interview

Table 14 gives results for the trainer's analysis.

Table 14: Knowledge and know-how identified using the classic self-confrontation method for activity "Case 2: Setting cams of a valve actuator"

Individual know(-how) (11)	**Collective know(-how)** (2)
Know how to prepare your tool box	
Know how to integrate operational feedback into its activities	
Know how to carry out the professional gesture so as not to degrade the equipment (removal of the cover of the actuator by tilting in order not to tear off the wires underneath)	Know how to work with others on the same activity. (Know how to coordinate the different workers of an activity. Know how to convince others of the interest to work together).
Know the role and operation of the equipment (role of cams and limit switches)	Know how to take safety risk into account (knowing how to give warning)
Know how to read the diagram	
Know how to put the cams in the right direction and the right order to be able to adjust them individually	
Know how to control the setting	
Know the importance of the action to be carried out (meaning of the work when putting back cams)	
Be able to listen to the noise representative of the operation of a material (closing of the valve on limiter = significant noise)	
Know how to place an indicator (in order to make a rotation of the wheel of the servomotor according to the demand)	
Know how to identify the potential consequences of the activity (risk of electrical insulation failure that can have an impact on the safety of the installation)	

The performance assessment of the methods applied for case 2 is not yet available. Results will come soon in table 15 and conclusions too.

Table 15: Criteria assessed for performance "Case 2: Setting cams of a valve actuator".

Method ->	**classic self-confrontation**	**SEBE/SPEAC-based method**
Replayed work activity (min)	About 10	
Individual knowledge	11	16
Collective knowledge	2	6
Tacit/explicit differentiation	N	34.7%
Replay interview duration (min.)	40	38
Total time for meeting (min.)	80	76

This table shows a similar time spent for the meetings but distributed differently:

- the SEBE/SPEAC method spends about 20 min before and 20 min after the RIW to question the SPEAC model,
- the classic self-confrontation method spends about 40 min before the RIW to replace the subject in the work situation and ends with the end of the RIW,
- the SEBE/SPEAC method identifies 45% individual knowledge more than the classic self-confrontation method, and 200% more regarding collective knowledge.

Some preliminary conclusions are yet worth to point out:

- Emphasize the help provided by the subject to the researcher. This helps for the subject to make sense about what he is about to undertake with the researcher (C03).

- Tenses of verbs used are important whilst questioning the poles of the SPEAC model. The appropriate tense questioning the two first poles of the SPEAC model is the present. This help the subject to think and answer as if he was about to perform the task, which is the sought effect. The appropriate tense for the last poles is the preterit, because it helps the subject to recall what he did, what he just viewed during the self-confrontation, which is also the sought effect (C04/C09).
- The subject had some difficulties to answer direct questions of poles of the SPEAC model likely by summoning directly a memory effort (Vermersch, 1994: 126). Prof. Lahlou suggested to use indirect or devious and multiple questions to replace each direct question (C04/C05). A series of questions is to be prepared in this aim.
- Questioning *Having to act* keep the subject close to the procedure: indirect or devious and multiple questions could help deal with this difficulty (C04/C05).
- Questions asked by the PhD researcher in the aim of identifying goals and sub-goals must be more numerous and more frequent (C16/C19).
- Concerns regarding novice colleagues help subjects to work the perspective-taking (C31).
- Subject had a positive feeling after the replay interview (C40) and said he was enthusiastic about the experiment.

Experiment reference TEST-IND-OP-C0
Assessment of the of the SEBE/SPEAC-based method (40 criteria) on pilot's activity
Associated assessment table: FORM 03 (in appendix 24)

During the activity, the pilot had to check the values of operating parameters on control panels.
The subjective movie watched in replay interview was a 4 min. video of the block-watch around. This time was scheduled by the negotiation done with the subject and his management: in order not to disturb the collective work in the team during the shift, it was said that the meeting would not last more than one hour, knowing that this would be enough to comment several minutes of the activity and assuming that several minutes would be enough to obtain a description of the activity that would make discovering most of the necessary related knowledge.
Reference: 20130606 part1 (OpJ), fichier 1 Go, deltat= 6 :36 -> 10 :40

Tables 3 A, B is giving the assessment criteria for the Preparation phase and the Capture phase resp. of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing each of these phases. All of them were met. No difficulty was encountered. In terms of improvement, a recommendation regarding date and time set up of the miniaturized camcorder was done (B02) in order to facilitate the replay with an additional point compared with the previous experiments: for easy analysis including the third person perspective video recordings, the timer of the miniaturized camcorder must be set up according to the time of the simulator numerical video system.

Table 3 C is giving the assessment criteria for the Analysis and Conclusion phase of the SEBE/SPEAC-based method.

C02- Selection of particular sequences is not disputed by the participants during replay interview

Only the beginning of the activity was replayed. This was not disputed by the subject for two reasons: i) this allowed the meeting to stand in the planned time range, ii) the professional practices are similar from one control panel to another (yet some specificities of parameters could not be seen such are the recording of measurements of vibrations for primary pumps or the use of charts for KRT chains).

C05- Replay interview: two first poles of SPEAC model questioning gives relevant data

The discussion about *Having to act* and *Knowing to act* completed each other and highlighted the gap between what is expected of the actor for the task according to the actor, and what he is able actually to do in the sense of knowing to do, "knowing to act". For example, the subject explained he did not know to justify immediately "all these alarms", or did not know the expected values for certain indicators. The deepening of these elements by questions highlighted what the subject could implement to compensate this gap between *Having to act* and *Knowing to act*. For example, the subject explained where to find the information or what to implement for the justification of a highlighted alarm. He explained that for indicators which he did not know systematically the expected values of, in case of deviation, the technical memo (in French: "fiche d'alarme") of an appearing alarm would explain the suitable behavior for this case.

This interview showed that answering questions of *Not Having to act* integrated implicitly the will to ignore "absurd way to act". For example, when the researcher asked the subject why he did not explained that he had to not press he emergency stop button, he said that it was logical. Unfortunately, transcribed dialogue is not available since the interview was audio-video recorded with a device for which audio cable plug was deteriorated and despites precautions the audio track was of very bad quality (see C39).

C09- Replay interview: two last poles of SPEAC model questioning gives relevant data

The discussion about *Wanting to act* completed Having to act, and highlighted the forgotten elements in situation. For example, the subject remained generalist whilst discussing *Having to act*, but in the discussion about Wanting to act, he tightened his analysis on a particular control panel (T20) in realizing that he had forgotten in his block-watch around to control some parts of this panel. This had not appeared in the comments during the viewing of the video which were mainly oriented on

"How do you carry out work activity?" From the subject's standpoint, such omission (control of the T20) was an error. Thus, the discussion about *Wanting to act* highlighted differences with *Having to act* and gave access to the subject's knowledge and competencies even though they were not implemented during the situation.

Discussion about the *Not Wanting to act* was short: the subject explained he did not remember or said "it was not conscious".

C39-Validation helps the researcher to validate/adjust the conclusions

Audio track of the replay interview recording is spoiled due to cable connection despite precautions.

C40-Validation gives the actors a useful feedback

The subject explained to be very pleased to have had such an exchange and to have viewed the video which helped him to identify some weaknesses (e.g. panel T20 not controlled) and to discover he could be concerned by tacit knowledge he could not even suspected because unconscious. His feeling after the replay interview was positive: interesting for him, feeling that it will bring something for others.

During the SEBE/SPEAC-based replay interview, the researcher was positioned facing the actor, and the screen was positioned on the side between the two: it was the actor who led the reading of the video (play/stop/replay) as suggested by the researcher at the beginning of the interview (Fig. 33).

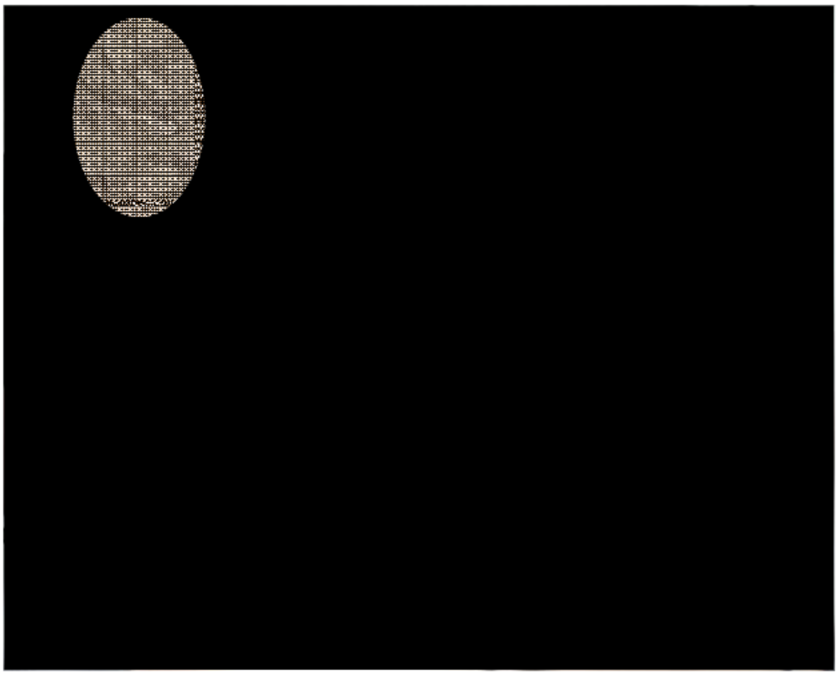

Fig. 33: Excerpt of the SEBE/SPEAC-based replay interview showing the pilot analyzing block-watch around: on the picture, the pilot rises his finger to the screen and just pressed the mouse in order to stop the replay video and make a comment.

Reference: interview replay\ OpJ 20130821\ fichier 1Go t=13:27

The researcher's analysis provided the results in table 16, where knowledge and know-how identified as potentially tacit are highlighted in yellow.

The potentially tacit knowledge described in table 16 (column "understand the control panel") by comments "reading information, fast sometimes" and "understanding information, fast sometimes" was identified through descriptions of block-watch around made by the subject emphasized by a metaphorical expression he used during the self-confrontation interview. To depict the way he was checking recorders, the pilot said "je regarde si ça tire droit" (I watch whether it goes straight). This meant the pilot did not read the values of parameters on the recorders. He confirmed this point when asked and explained that for certain recorders or indicators, it was easy and fast to check a signal position rather than read the value according to the scale of the recorder and compare it with the expected value. This was done without losing any reliability on values. When he was asked whether

this practice was his own, he said that most of his colleagues (even all) did so. When he was asked where he was taught this practice, he could not find any answer.
This tacit knowledge, identified upon a metaphorical description of the work activity, gives a research topic interesting to investigate: the associated assumption is that this experienced pilot (duration in the position: 5 y.) developed an implicit knowledge which is shared with experienced peers but perhaps not with the novices. This point gave rise to additional experiments in order to characterize this potential typical implicit knowledge using SEBE (Fauquet-Alekhine & Daviet, 2015) but is not presented here.

Table 16: Knowledge identified using the SEBE/SPEAC-based method for the pilot's activity "block watch-around".

Individual level of the activity					
Fields of competencies	Develop a general representation of the state of the process	Understand the control panel	Perform a safety check-up	Fix a problem	Cope with lack of knowledge
Knowledge	-knowing the physical process to anticipate the forthcoming phenomena -knowing the relevant physical parameters to better anticipate the forthcoming phenomena -knowing the equipment related to the physical parameters to perform an efficient and relevant check-up	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related process equipment to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing the general operating and technical specifications (OTS) to perform an efficient and relevant check-up -knowing about the amendments of OTS to perform an efficient and relevant check-up	-knowing the relation between control equipment and related OTS requirements to undertaken the appropriate actions	-knowing in which documents or data base find the answer(s) in order to undertake a relevant analysis
Collective level of the activity					
Fields of competencies	Share the representation of the state of the process				Cope with lack of knowledge
Knowledge	-knowing the team organization to identify the appropriate time to exchange with the colleague(s) co-piloting the reactor				-knowing colleagues' competencies to ask relevant help

The criteria assessed for efficiency of the method are summarized in table 17.

Table 17: Efficiency criteria summarized for the test regarding the pilot's activity "block watch-around".

Method ->	**SEBE/SPEAC-based method**
Replayed work activity (min)	4
Individual knowledge	13
Collective knowledge	2
Tacit/explicit differentiation	46.1%

Replay interview duration (min.)	20
Total time for meeting (min.)	45

Limits of these first results lie in:

- Difficulties of the subjects encountered to answer the questioning of *Not Wanting to act* may suggest to ask questions about this pole differently, not just by the direct and explicit question "what did not you want to do?"

Conclusion and relevant points of these first results are:

- The subject accepted very easily the subcam and seemed to participate with enthusiasm to the experiment including replay interview.
- From the technical standpoint, synchronizing any camcorder or video record together (including the simulator system) is crucial for easier analysis and audio plug must be checked.
- During the interview, metaphorical expression describing the work activity may help to identify key points related to competencies.
- Questions about the four poles of the SPEAC model in their positive and negative form gives indeed relevant information which come in addition or complete what produces the self-confrontation. It even gives access to the subject's knowledge and know-how even when they are not summoned during the studied situation.
- The modalities for questioning the poles of the SPEAC model might be rethought: as suggested by Prof. Lahlou is the previous experiment, indirect questions could help obtaining more relevant and diverse material.
- The questioning of each pole completes one another (C05/C09). For example, answering *Wanting to act* brought forgotten items for *Having to act*.
- Answering questions of *Not Having to act* integrates implicitly the will to ignore "absurd way to act" (C05).
- Subject had a positive feeling after the replay interview: interesting for him, feeling that it will bring something for other, having discovered he could be concerned by tacit knowledge he could not even suspected because unconscious (C40).

Experiment reference TEST-IND-AGT-C0
Assessment of the of the SEBE/SPEAC-based method (40 criteria) on field worker's activity
Associated assessment table: FORM 04 (in appendix 24)

During the activity, the field worker had to find the parts of equipment and apply the associated lines of the modus operandi.
The subjective movie watched in replay interview was a 11 min. video of the activity, beginning when receiving the request of the task by phone in the technicians' room and ending when locating the first valve of the modus operandi. This time was scheduled by the negotiation done with the subject and his management: in order not to disturb the collective work in the team during the shift, it was said that the meeting would not last more than one hour, knowing that this would be enough to comment several minutes of the activity and assuming that several minutes would be enough to obtain a description of the activity that would enable discovering most of the necessary related knowledge.
Reference: 20130604 MSI (AgTFr)\ fichier 1 Go (t=00:00 to 11:00)

Tables 3 A, B is giving the assessment criteria for the Preparation phase and the Capture phase resp. of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing each of these phases. All of them were met. No difficulty was encountered. In terms of improvement, a recommendation regarding date and time set up of the miniaturized camcorder was done in order to facilitate the replay with an additional point compared with the previous experiments: for easy analysis including the third person perspective video recordings, the timer of the miniaturized camcorder must be set up according to the time of the simulator numerical video system. Cautions must be taken also about audio plug as mentioned in previous experiment.

Table 3 C is giving the assessment criteria for the Analysis and Conclusion phase of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing this phase. Some of the criteria gave rise to comments that are discussed here.

C02- Selection of particular sequences is not disputed by the participants during replay interview

The beginning of the activity only was replayed. This was accepted by the subject for two reasons: i) this allowed the meeting to stand in the planned time range, ii) it made sense for him to discuss the professional practices until finding the first piece of equipment; perhaps he would have been frustrated if the replay had stopped before this kind of subtask had been achieved.

C04- Replay interview: two first poles of SPEAC model questioning seems correctly understood by the actor-participant

Having to act is essentially described by the subject from the procedure RFLL027 which is given at the beginning of the meeting and he had to apply in the situation. He explained he had to find the pieces of equipment. He explained that what helped him to find some certain VVP valves was his knowledge of the safety events feedback and that impressed him (e.g. a colleague who manipulated the wrong valve: GCT instead of VVP). He also explained that premises are identified by a letter and three digits: the letter W is designates anything which is located around the reactor building (file 1 GB t= 04:30). It is amazing that at this stage, the subject did not specify that the digit of the hundreds helped him to assess the level were to find equipment; for example, if he wanted to go in a room type 700 and it read 600 on a board, he knew that he had to climb. The subject gave this precision much later (file 1 GB t=21:00) when the researcher asked him if there was a logic continuation in the numbering of the premises. The answer was that there is no logic except for the digit of the hundreds. *Not Having to act* was defined by the subject as opposed to what he said *Having to act* (file 1 GB t=03.30).

C09- Replay interview (one actor): two last poles of SPEAC model questioning gives relevant data

The questioning highlighted a conflict between poles *Having to act* and *Wanting to act*: before viewing the subjective film, the subject explained his need to take "official roads" (regulatory) to move (*Having to act*) while, if he had been alone, he would have overpassed pipes, fences, low walls. But he had to set an example to the observer (the researcher). Then, after viewing the film, the subject explained not wanting to take too long paths (*Not Wanting to act*). Did this conflict of poles (*Having to act* vs *Wanting to act*) give rise to suffering at work? The issue was not raised. However, the researcher's feeling during interview is that if there was generation of suffering, it was minor or negligible. The questioning of *Wanting to act* highlighted another interaction on this point: the subject explained he could not take shortcuts because of the presence of the observer (*Being able to act).* This is interesting for the conceptualization of the square of the action. This highlights the dynamics of the square of the perceived action. The pole *Having to act* induced 'take regulatory paths', the pole *Being able to act* induced "cannot take shortcuts because of the presence of the observer", and the pole *Wanting to act* induced "do not want to take too long paths". The resulting equation is thus:

[Having to act + elements of context (e.g. observer)] + (Not) Being able to act

=> conflict (Wanting to act vs Being able to act)

C21- Subjects' conscious mental representations of the expected results are discussed in individual interview

The subject added that he had to read this sheet before leaving the field and that he projected in his mind mental images of the valves to operate, and when he did know the valves, he mentally projected the premises where they could be (indirect representation).

During the SEBE/SPEAC-based replay interview the researcher was positioned facing the actor, and the screen was positioned on the side between the two: it was the actor who led the reading of the video (play/stop/replay) as suggested by the researcher at the beginning of the interview (Fig. 35).

Fig. 35: Excerpt of the SEBE/SPEAC-based replay interview showing the field worker analyzing isolation of steam generator #1 due to high level of radioactivity inside: on the picture, the worker holds the mouse in order to stop the replay video and make a comment.

Reference: interview replay\AgTFr 20130829 (VVP)\ interview replay AgTFr (lignage RFFL27) t=10:12

The researcher's analysis provided the results in table 18, where knowledge identified as potentially tacit are highlighted in yellow.

Table 18: Knowledge identified using the SEBE/SPEAC-based method for the field worker's activity "Isolating steam generator #1 due to high level of radioactivity inside"

Individual level of the activity					
Fields of competencies	Read a RFFL (specific document) (1)	Move on the plant	Identify the equipment	Implement Lockout-tagout[30] for equipment	Apply a RFFL (specific document) (1)
Knowledge	-knowing the documentary system in which the RFFL fits to understand its interaction with the whole set of related procedures -knowing the reading rules of a RFFL in order to interpret it correctly	-knowing the isometry of buildings to find the equipment through the shortest way -knowing the nomenclature of premises to find the equipment using the MO -knowing which equipment is associated with specific physical process to mentalize the location of the equipment and then find it quicker - knowing which equipment is associated with specific physical process to read and understand more easily a mechanical drawing	-knowing the benefits of exchanging with colleagues before going into the field to find faster the equipment -knowing the best practices applied to identify the equipment to identify it without doubt(2) -knowing the rules and the tags used to tag the equipment to read/interpret a functional tag -knowing the benefits of having in the field a mechanical drawing to find faster the equipment	-knowing the rules and the tags used to tag the equipment to recognize a sign of lockout -knowing the rules to lock & tag a piece of equipment from the technical standpoint to obtain a quality result -knowing the organizational principles of lock & tag to comply with the prescriptions(3) -being conscious of the implications of a missed lock & tag work to be motivated to obtain a quality result	-knowing the reading rules of a RFFL in order to interpret it correctly -knowing the specificities of equipment in order to read and understand information and/or to act on the equipment
Collective level of the activity					
Fields of competencies	Share the representation of the activity	Coordinate the forthcoming cooperation	Communicate with the co-worker(s)	Use co-workers' competencies	Share the operational feedback
Knowledge	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	-being conscious that the PjB is a specific time to plan conjoint actions -being aware that the PjB is a specific time to check communication means -being aware that the PjB is a specific time to plan communication points	-knowing the means at disposal to communicate in due time and correctly -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do	-knowing the protocol for debriefing to have an efficient debriefing -being conscious of the benefits of feedback sharing to improve future activities

(1)The RFFL is a kind of procedure not often used.
(2)Identifying a piece of equipment on the basis of a lockout tag without checking the stricken tag on the equipment may lead to a mistake.
(3)Especially certain actions may not be performed without prior real-time manager's agreement.

Example of access to the individual implicit knowledge "know the reading rules of a RFFL in order to interpret it":

[30] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a lock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

Whilst questioning *Having to act* and *Knowing to act*, deviations from what must be done appeared. The subject explained having to correctly read the whole form before leaving to go in the field (file 1 Go t= 01:40 reading the line about ARI at t=02:50) and during self-confrontation (file 400 Mo t=14: 49), the subject explained having forgotten to read the first lines in red stating the ARI port. This explanation was induced by a comment from the subject himself watching the video "this I should have read it before" followed by a video break done by the researcher who incorporated the comment "you should have read it before? '' The subject explained he passed quickly to the first box of the flowchart forgetting to read the few lines in red just above: they were additional comments to describe the task done inside the boxes.

The tacit knowledge was not on the fact that he had to read but on the fact that he had to understand these additional comments apparently respecting writing standards which are not taught. The subject did not remember how he learned how to understand it.

The criteria assessed for efficiency of the method are summarized in table 19.

Table 19: Efficiency criteria summarized for the test regarding the field worker's activity "Isolating steam generator #1 due to high level of radioactivity inside".

Method ->	**SEBE/SPEAC-based method**
Replayed work activity (min)	11
Individual knowledge	15
Collective knowledge	17
Tacit/explicit differentiation	59.3%
Replay interview duration (min.)	30
Total time for meeting (min.)	45

Limits of these results lie in:

- For this test phase, the subjective film of the activity was watched partially. Despite the facts that this was not disputed by the subject performing the task and that the SEBE/SPEAC-based method gave results in terms of what make the competencies of the worker, it is important to keep in mind that when applying the method, it might be worse viewing the whole activity or at least several parts of it. This would lead to longer phases of reply interview and consequently of analysis.
- Using direct questions to explore the poles of the SPEAC model seems not so efficient: we had difficulties in obtaining relevant information with such questions whilst applying the protocol to individual activities. Answers to these questions must be reached through indirect questions as suggested and illustrated during the experiments by Prof. Lahlou.

Conclusion and relevant points of these first results are:

- Cautions about timer synchronization and reliability of audio recording are confirmed.
- Subjects' spontaneity to accept the subcam and to participate to the replay interview are confirmed.
- The pole *Having to act* is often answered very close to the prescribed task. These findings suggest that indirect questions could help to obtain relevant answers rather than using direct questions as it was done. Prof. Lahlou noticed that the interviewed subject's perspective-taking of a novice worker could be one of the ways to find indirect questions regarding the pole *Having to act*.
- A conflict appeared between poles *Having to act* and *Wanting to act* shedding light on the dynamic of the SPEAC model. The dynamic of the model must be analyzed because its description may open new keys of understanding of work activities.
- Subjects elaborate indirect mental representations when the targeted piece of equipment is unknown. This may rely to a combination of episodic memory and enactment to be analyzed.
- Tacit knowledge may be identified upon a metaphorical description of the work activity.
- Potential typical implicit knowledge may be characterized using SEBE.

Experiment reference TEST-COLL-OP-AGT 01
Assessment of the of the SEBE/SPEAC-based method (40 criteria) on collaborative activity
Associated assessment table: FORM 05 (in appendix 24)

Tables 3 A, B is giving the assessment criteria for the Preparation phase and the Capture phase resp. of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing each of these phases. All of them were met. No difficulty was encountered.
Table 3 C is giving the assessment criteria for the Analysis and Conclusion phase of the SEBE/SPEAC-based method. These criteria have been rated by the PhD researcher after performing this phase. Some of the criteria gave rise to comments that are discussed here.

C01/02
Due to the length of the video recordings (about 1h each), a selection of sequences was done by the researchers.
For the field worker's activity, sequences chosen concerned:

- "REA configuration" preparation between field worker and pilot in control room,
- "REA configuration" preparation by the field worker alone in control room,
- field worker's first exchange with pilot in control room about "REA configuration" preparation,
- "REA configuration" preparation between field worker and pilot in control room,
- REA leak activity in controlled zone including exchanges by phone between field worker and pilot.

For the pilot's activity, sequences chosen concerned:

- Turbine coupling and contribution of the pilot within the team,
- "REA configuration" preparation between field worker and pilot in control room,
- Decrease of nuclear reactor power and contribution of the pilot within the team,
- Exchanges about radiologic concerns by phone between field worker and pilot in control room,
- Exchanges about REA leak by phone between field worker and pilot in control room.

For the cross-replay interview, sequences chosen concerned:

- Fist and second exchanges between field worker and pilot in control room,
- Pilot working with supervisor in control room,
- Ambiance and context in the control room and in the controlled zone at the same moment.

Chosen sequences for discussions were well accepted by the participants. Even when the outside researcher asked participants to suggest additional sequences which could be relevant in their opinion, none was added.

C04/05: Replay interview with one actor: two first poles of SPEAC model questioning seems correctly understood by the actor-participant / gives relevant data according to the researcher's expectation

> Subjects may answer questions not deep enough. For example, when the field worker was asked what he had not to do, he answered first on the basis of the procedure and to the pilot's requests expressed during the preparation phase in control room, then he evoked details noticed in controlled zone and was ready not to describe them. The researcher had to stop him and ask for precise description:

Fragment 6

Field Worker (FW):	[…] After it is things I noticed locally (.) uh:::: but however no [the:::
PhD researcher (R):	[Wait, things you noticed locally (.) What for example?

Reference: simu MS(I) 2013 12\ MSI 2013 12 J5 IR\MSI 2013 12 IR PhFA-AgTR\ DSCN4411.AVI (t=02:36)

This gives an example of the necessity for the researcher to be ready at any time to lead and help the subject to a complete answer. Despite preliminary explanations given by the researchers regarding what they are seeking, subjects do not evaluate how details may be important. This may be due researchers' explanations not clear enough, or to the fact that they are not used to analyzing activities to appreciate well the value of details, or to their desire to give other details at once. The trap to be avoided by the researcher is to focus on writing or written notes or on the next questions and being unable to notice this very short evocation.

C10-11-14-15: Replay interview with both actors: two first / last poles of SPEAC model questioning seems correctly understood by the actors-participants / gives relevant data according to the researcher's expectation / subjective replay interview causes actors' spontaneous participation / gives relevant data according to the researcher's expectation

Direct questions were avoided: following the individual interviews, researchers found it more relevant to question SPEAC model poles through selected video sequences. The purpose was thus to identify sequences were generating conflict or accordance between poles: subject 1 wants but subject 2 cannot, subject 2 wants and subject 1 can and wants for example.

Doing so, it led to investigate perspective-taking and perception of collaborative activities in cross-replay interview. This work is presented in a section thereafter.

Several criteria were easily matched due to the fact that the work situation involved several subjects and therefore disturbance, collective representation, coordination, interactions, perspective-taking.

C17/C18: Subjects' feelings including the disturbance are discussed in individual interview/collective interview

C23: Representation of collaborative activity is discussed in collective interview

C25/C26: Factors of coordination are discussed in individual interview/collective interview

C27/C28: Subjects' interactions are discussed in individual interview/collective interview

C31/C34: Post-analysis allows the researcher to analyze/identify subjects' perspective-taking / and consequences

Analysis of recordings of subjective videos and replay interviews (individual and crossed) completed by in situ observations led to identification of fields of competencies and related knowledge for collaborative activity between field worker and pilot.

Tables 30 and 31 give the data for the field worker's interview, 32 and 33 for the pilot's interview, where knowledge identified as potentially tacit are highlighted in yellow. Regarding the cross replay-interview, such identification was not undertaken because the cross-replay interview focused on perspective-taking and perception of collaborative activity.

During replay interview, it appeared that some of the potentially tacit knowledge were part of the common knowledge that was not specific to the task but part of the common core of the profession. For example, "know the meaning of O/C or other terms for the equipment" is a knowledge expected to be able to read almost each document used by a field worker. This could lead to the assumption that a mistake is done when considering all what is not explicitly told by the worker as tacit. This assumption is not right since workers indeed explicit core knowledge such as: "know the nomenclature of premises" (table 18) or "know to lockout or unlock applying the related MO" (table 30).

It is noted that these concern simulated situations. Some fields of competencies are thus different from what could be expected on the industrial unit. This is clearly illustrated by the field of competencies "Moving on the simulator" rather than "Moving on the plant" as it was identified for the above field worker's activity (see table 18).

In addition, the analysis of the replay interviews being third person type, practical advice must be noticed. In case of availability of audio recording only, it is important that the analyst gives oral cues such during the interview:

- Saying the name of who we speak about/to or who we watch on the video,
- What part of activity we watch,
- What time is recorded on the watched video.

Of course, these elements may be written on the analyst's notes, but these cues may help the analyst to save time when analyzing the recordings.
However, the analysis of both audiovideo and audio recordings leads to the conclusion that analyzing the replay interview from the audiovideo recording helps the analyst to save a lot of time: viewing actors allows the analyst to identify which moments may be skipped and it reduces the time spent for the analysis.

Tables 30 & 31 for field worker's fields of competencies and knowledge issued from the SEBE/SPEAC method.

Tables 32 & 33 summarize fields of competencies and knowledge for pilot's activity issued from the subjective replay interview undertaken by the outside researcher, Dr. Le Bellu. The structure of the interview was:

- Explaining the purpose of the experiment (analyzing work activity) and the goal of the interview (identifying what makes competencies).
- Recalling time constraints for the interview.
- Asking a brief description of the position.
- Asking what was the state of installation and the expected final state in the experienced work situation with a link with the global goal of the activity.
- Questioning the subject's opinion about the way it worked.
- Explaining the replay interview.
- Performing the replay interview.

The third step "Asking a brief description of the position" was the opportunity for the outside researcher to obtain information about fields of competencies:

- Watching parameters in control room, the global goal of which is to control that parameters are at expected values (know where it comes from), checking alarms.
- Configuring circuits (remote control).
- Managing incidental situation within the team.

The fourth step "Asking what was the state of installation and the expected final state" was the opportunity for the outside researcher to obtain information about task-related fields of competencies:

- Turbine coupling.
- Interacting with members of the team according to the position.
- Undertaking a pre-job briefing for an activity .
- Sharing the representation of the state of the process with the help of the supervisor.

These items are completed by the tasks listed in table 21 (timeline of the pilot's activities):

- Preparing/dealing with a circuit configuration to be performed in the field (with a field worker).
- Managing instabilities of the reactor or increasing/reducing the power.
- Dealing with radiologic concerns.

Table 30: Knowledge identified using the SEBE/SPEAC-based method for the field worker's activity during collaborative activities (hydraulic configuration) in simulated situation.

Individual level of the activity							
Fields of competen-cies	Use a MO with its various parts to fill in	Move on the workplace	Work in a controlled zone	Prepare the documents	Identify the equipment	Recognize Lock & Tag[31] for equipment	Act on the equipment
Knowledge	-reading and understanding what is asked to be able to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality	-knowing the buildings to find the equipment through the shortest way -knowing the nomenclature of premises to find the equipment using the MO -knowing which equipment is associated with specific physical process to go there directly - knowing which equipment is associated with specific physical process to read and understand more easily a mechanical drawing	-knowing the rules to enter, to stay, to work in different types of controlled zone. -knowing radiologic risks to keep oneself at an appropriate distance from a radiologic source -knowing the safety protections to protect oneself with individual safety equipment -knowing the rules to care oneself in case of exposition/contamination in order to reduce pathological consequences -knowing the metrology available to require it and protect oneself with appropriate measurements -knowing which document are necessary to work in controlled zone in order to avoid administrative issue	-knowing the documentation organization to complement the documents provided for the activity if need be -knowing the implicit standard of color to apply relevant colors on the mechanical drawing to make it simpler to read in the field -understanding the mechanical drawing to make an understandable link with the MO - understanding the mechanical drawing to translate it as a MO	-knowing the benefits of exchanging with colleagues before going into the field to find faster the equipment -knowing the best practices applied to identify the equipment to identify it without doubt(2) -knowing the rules and the tags used to tag the equipment to read/interpret a functional tag -knowing the benefits of having in the field a mechanical drawing to find faster the equipment	-knowing the rules and the tags used to tag the equipment to recognize a sign of lockout -knowing the organizational principles of lock & tag to comply with the prescriptions(3) -being conscious of the implications of a missed lock & tag work to verify the lock & tag if need be	-knowing the meaning of Open/Close or other specific terms in order to read information and/or to act on the equipment -knowing what is asked and means to compare it with what can be done (especially when several tasks may opposed each other) - knowing risks related to action on equipment to avoid unexpected issue - knowing when to open/close the valves to avoid surprising movement of liquid for the pilot
Collective level of the activity							
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Communicate with the co-worker(s)	Take care of the co-worker's need	Managing several tasks in parallel		Share the operational feedback
Knowledge	-knowing co-workers' competencies to make judicious requests	-being conscious that the PjB is a specific time to share mental representation	-knowing the means at disposal to communicate in due time and correctly -being	-knowing the needs of each other and what each other can provide to the other to help	-knowing what to do to stop an activity safely and restart it safely		NOT OBSERVED (end simulation)

[31] Lockout-tagout or lock and tag is a safety procedure which is used in industry and research settings to ensure that dangerous machines are properly shut off and not started up again prior to the completion of maintenance or servicing work. It requires that hazardous power sources be "isolated and rendered inoperative" before any repair procedure is started. "Lock and tag" works in conjunction with a lock usually locking the device or the power source with the hasp, and placing it in such a position that no hazardous power sources can be turned on. The procedure requires that a tag be affixed to the locked device indicating that it should not be turned on. The opposite operation is "unlocking".

	-being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do	through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange -knowing the team organization to identify the appropriate time to exchange with the colleague(s)	conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability	the co-worker if need be	-knowing the priority of activities to accept switching between tasks or refuse it		

Table 31: Efficiency criteria summarized for the test regarding the field worker's activity.

Method ->	**Individual replay interview SEBE/SPEAC-based method**
Replayed work activity (min)	8
Individual knowledge	27
Collective knowledge	13
Tacit/explicit differentiation	65.0%
Replay interview duration (min.)	30
Total time for meeting (min.)	60

…/…

Table 32: Knowledge identified using the SEBE/SPEAC-based method for the pilot's activity during collaborative activities (hydraulic configuration) in simulated situation.

Individual level of the activity						
Fields of competencies	Develop the overall representation of the state of the process	Understand the control panel	Ensure the nuclear safety level required	Use a MO with its various parts to fill in	Understand the control panel	Act on the control-command
Knowledge	-knowing the physical process to understand physical phenomena -knowing the relevant physical parameters to check to identify/understand the changes of physical phenomena -knowing the equipment related to the physical parameters	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related industrial process to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing the general operating and technical specifications (OTS) to perform a relevant and efficient check-up -knowing the amendments of OTS to perform a relevant and efficient check-up	-reading and understanding what is asked to be able to perform the task and fill in the form correctly -knowing the structure of a MO to fill in what is expected to produce a final product of quality	-knowing where to find information to perform an efficient and relevant check-up -knowing the relation between control equipment and related industrial process to better understand the phenomena - reading information, fast sometimes to perform an efficient check-up -understanding information, fast sometimes to perform an efficient check-up -knowing what must not be touch to avoid mistakes -knowing the causes of alarms to deal with problems	-knowing the specificities of equipment in order to read information and/or to act on the control-command properly -being aware of specific physical phenomena subsequent to certain control-command actions to avoid doing too much or doing too slow(1)

Collective level of the activity						
Fields of competencies	Use co-workers' competencies	Share the representation of the activity	Communicate with the co-worker(s)	Take care of the co-worker's need	Manage several tasks in parallel	Share the operational feedback
Knowledge	-knowing co-workers' competencies to make judicious requests -being conscious of the peers' possible help to ask co-workers' help asap -knowing own limits to let co-workers' do	-being conscious that the PjB is a specific time to share mental representation through perspective-taking -being aware of the benefits of perspective-taking in order to share mental representation of the activity -being aware of the benefits of sharing mental representation of the activity to take time to exchange	-knowing the means at disposal to communicate in due time and correctly -being conscious of the co-worker's workload to call him at appropriate moments - before calling , knowing what information to give/to ask to exchange efficiently -being conscious of the co-worker's need to give him relevant information at	-knowing the needs of each other and what each other can provide to the other to help the co-worker if need be	-knowing what to do to stop an activity safely and restart it safely -knowing the priority of activities to accept switching between tasks or refuse it	NOT OBSERVED (end simulation)

		-knowing the team organization to identify the appropriate time to exchange with the colleague(s)	appropriate time -knowing the organizational standards of communication (TWC) to communicate with reliability -be conscious that giving the sense of a request leads to higher performance in order to explain a request with enough details			

Table 33: Efficiency criteria summarized for the test regarding the pilot's activity.

Method ->	**Individual replay interview SEBE/SPEAC-based method**
Replayed work activity (min)	12
Individual knowledge	21
Collective knowledge	15
Tacit/explicit differentiation	66.6%
Replay interview duration (min.)	42
Total time for meeting (min.)	60

Appendix 26 : Set of indirect questions to question the SPEAC model and the activity goals

These statements may be used as indirect questions to question the four poles of the SPEAC model. During an interview, all questions must not be asked. It is suggested to tick a selection of questions per pole during the pre-analysis phase of the SEBE/SPEAC protocol. The selection id performed according to the analyst's assessment of their relevancy regarding the activity analyzed. Ticking the questions during the pre-analysis phase allows the analyst to find quickly which questions must be asked during the replay interview.

Having to act

The tense to be used during the interview is present.
The direct positive question is: What do you have to do for such situation/activity/case?
The indirect questions may be:

- Which instructions are given, by who?
- Are you given particular instructions, by who?
- Which documents are given, by who?
- What are the written requirements/rules given?
- How would you define the activity you have to do?
- What are you expected to do, by who, by what?
- What a novice must do for such situation/activity/case?
- What is the overall goal as defined by the order given for such situation/activity/case?
- What is the overall goal as defined by the organization for such situation/activity/case?
- What is the overall goal as defined by the prescription for such situation/activity/case?
- What is the overall goal as defined by yourself for such situation/activity/case?
- Do you establish for yourself particular rules to follow for such situation/activity/case?
- What is your own representation of what must be performed?

The direct negative question is: What don't you have to do for such situation/activity/case?
The indirect questions may be:

- What do others expect yourself not to do?
- What is expected to be avoided?
- What is forbidden?
- What were the rules missing?
- What do you forbid you to do?
- What a novice must not do for such situation/activity/case?
- Are you update of what some others do while must not be done?

Knowing to act

The tense to be used during the interview is present.
The direct positive question is: What do you know to do for such situation/activity/case?
The indirect questions may be:

- What are the prerequisites to know before performing such activity?
- What a novice must know for such situation/activity/case?
- If you were novice, what would you expect to be taught for such situation/activity/case?
- How do you know what is expected from you?

The direct negative question is: What don't you know to do for such situation/activity/case?
The indirect questions may be:

- According to the (sub)goals you defined earlier, what were the knowledge / know-how missing?
- What may be thought as a pre-requisite in terms of knowledge or experience and be found useless afterwards?

Being able to act

The tense to be used during the interview is preterit.

The direct positive question is: What were you able to do for such situation/activity/case?

The indirect questions may be:

- Did you had all means at your disposal?
- What a novice must be able to do for such situation/activity/case?
- If you had been novice, what additional means would have been necessary?
- What kind of help could/should you expect from other professions?

The direct negative question is: What were not you able to do for such situation/activity/case?

The indirect questions may be:

- According to the (sub)goals you defined earlier, what were the means missing?
- What were the tools missing?
- What were the help missing?
- What was impossible to do?
- Which difficulties did you encounter?
- Are there things others did instead of you?

Wanting to act

The tense to be used during the interview is preterit.

The direct positive question is: What did you want to do for such situation/activity/case?

The indirect questions may be:

- Did you do all what you wished to do during this activity? What was it?
- What did you want to reach?
- What did you force yourself to do due to the fact that you were observed?

The direct negative question is: What didn't you want to do for such situation/activity/case?

The indirect questions may be:

- What did you want to avoid?
- What would you not have to do if you would be novice in the case?
- Do you feel you did anything you wanted to avoid?
- Are there things you did but think you should have let others do it?
- At this time of the video, is there anything you have done differently from what you planned to do?
- What did you avoid due to the fact that you were observed?

Goal-oriented questions during replay interview

The direct question may be: What is/was/are/were yours goal(s) for such situation/activity/case?

The indirect questions may be:

- For which reasons you do/did that?
- For which reasons you avoid that?
- What would you say here in this situation at this time to a novice colleague?
- Do you define (sub)goal(s) for the activity?
- What is your following objective at this time of the video?
- What are you about to do at this time of the video?

Appendix 27 : WANO Statement form of selection as a strength in the Area "Training Quality"

for the application of the SEBE/SPEAC method
source: the WANO peer review evaluating Chinon NPP in November 2016

Chinon Peer Review November 2016
Reviewer(s): L. Pironkov

AREA TQ

Innovative approach to On-the-job training on human performance tools

PERFORMANCE OBJECTIVE

TR.1-14 In-plant, simulator and laboratory training and evaluation, such as on-the-job training and task performance evaluations, accurately represent plant conditions. Trainee controls in place during in-plant training ensure that inadvertent equipment manipulations are avoided.

Strength TQ.1-1

SUMMARY

Proposed innovation implements special techniques for conducting on-the-job training sessions on human performance tools, which is closer to the field. The objective is to raise the level of skills on personnel human performance in order to consequently improve the quality and safety levels of work activities. This method is also applicable as a knowledge management tool.

DETAILED INFORMATION

The training course has incorporated innovating techniques for an in-depth analysis of the training needs and for an improved collective debriefing of the simulated situation; on the technical side, the use of subjective cameras was introduced (miniature camera mounted on safety glasses to produce a first-person video of the work activity (Fig.1a) and later used for the debriefing (Fig.1c)). This training course has been designed as "in situ simulation": delivered on the real installation with mimicking actions on the equipment; the procedures, the displacements, the work practices, however, are real.

This course is planned every two-year. In 2015, 14 out of 15 teams from the Operations department of the plant followed this training. The course is planned for the Operations department in 2017, 2019; it will be implemented in other departments.

a [redacted] b [redacted] c [redacted]

Fig. 1a, b & c: a) example of subjective capture of activities in situation, b) selection of sequences of interest before debriefing, c) collective debriefing of the activities.

BENEFITS

Up to now, trainees' (front line managers, operators, field workers) feedback of the training course is strongly positive: they recognize its actual contribution to practice improvement through the self-confrontation to the first-person video, innovating nature, easy implementation, interactive properties and high level effectiveness. Thanks to the use of videos in training, trainees can easily and quickly be aware of what contributes to their errors and be conscious of their progress.

The first training cycle has already improved safety indicators. It has stabilized the occurrence of safety events associated with non-compliance to the use of HP tools within the Operations teams. Before, the trend was ascending. Compared with other departments that followed the traditional training the results of the Operations departments who followed this innovative training session were better.

CONTACT INFORMATION

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According to WGP01, this is a Type 1 Strength.

FYI (from WGP01):

Type 1: A first type of strength demonstrates a new, higher level of excellence that would benefit other plants in the industry to emulate. This type of strength should be considered as "redefining" excellence. Consequently, the team should be very thorough in identifying performance at a station as this type of strength and recognise that most in the industry will likely attempt to adopt the strength at their station. As a result, these strengths will likely drive change in the industry.

Type 2: A second type of strength is the one that is helping to substantially improve station performance and should be continued. It could be focused on results, processes, behaviours, or techniques that are likely to drive results. When focused on results, the team should document the higher-level results and provide a context on how these results were achieved. When focused on processes, behaviours, or techniques, the reviewer should recognise that there are many ways of achieving results, and be careful not to ratchet the industry in a specific technique that was beneficial at one plant but may not be as beneficial (or needed) at other plants.

Appendix 28 : Hydraulic configuration training sessions (CLIG training sessions) on Chinon NPP Training Center

I-Decontextualization

Decontextualized simulation designates a training approach designing simulated situations, the context of which is quite different from the usual professional context of trainees (for example: being trained on a serious game relating to military management in war field in order to improve the leadership of managers in pharmaceutical laboratories. Indeed, it was shown that training transverses professional practices in decontextualized SimS could significantly increase the performance for experienced workers (20%) compared to the contextualized training (10%) (Fauquet-Alekhine & Boucherand, 2016a). The assumptions were thus that working in decontextualized situation would improve performance and it would help trainees to perceive the contextualized SimS on full scale simulator less disconnected from their daily environment (contrast effect; see Plous, 1993).

Specifications for a high-performance design of the decontextualized simulation training are:

- The decontextualized simulated situation must be far enough from the technical gestures associated with the basic fundamentals of the trainees' profession. This is why it is better to address transversal professional practices in decontextualized training.
- An adjustment of the social valuation dimension of the decontextualization must be carefully conducted:
  "Analysis of trainees' feedback in vocational training showed that if trainees feel 'infantilized' or 'patronized' (these are their own words), they do not get involved in training and are not ready to learn." (p. 3) For example, it is better to train nuclear reactor pilots on HD virtual flight simulators rather than ask them to play surgeon with a kid toy.
  This social valuation may come from the profession simulated or from the values it conveys, such as improving safety, struggling for good against evil or helping someone.
- An adjustment of the attractive dimension of the decontextualization must be carefully conducted:
  "The attraction dimension also contributes to promoting acceptance of the decontextualized simulated situation (Huang et al., 2010a). This dimension may be based for example on the social valuation dimension (being attracted by a socially valued profession), on the power conferred by the situation (being the boss) or the playful dimension (case of Serious Games)." (p. 3)

In practice, for the 2016 CLIG training session, two decontextualized workshops respecting these criteria were chosen:

- Workshop #M - Mounting an insufflator: the medical context in far from the nuclear industry context, the profession of physician (medical garments were provided) is socially valued and the task suggested is attractive by its mechanical aspect.
- Workshop #F - Co-piloting a Robin DR 400 plane: the aviation context in far from the nuclear industry context, the profession of pilot is socially valued and the task suggested is attractive by its playfullness.

II-Assessment of the 2015 CLIG sessions

The Training Center undertook a synthesis assessment at the end of each training session. The questionnaire used (hereinafter called the "CLIG Training Center questionnaire") was a paper form individually filled in by trainees at the end of each training session. The questions were:

1-Do you think you have achieved the objectives of the training session?

2-Are the themes and contents adapted to the objectives of the training session?

3-Do the sequence of topics and content seem coherent to you?

4-Does the balance between theory and practice seem correct to you?

5-Are you very satisfied with the animation?

6-Does the membership of the group allow you work and have productive exchanges?

7-Is the documentation satisfactory?

8-Is the contributions of this training applicable in your professional activities?

9-Did you have the knowledge, skills and experience required for this training session?

For this questionnaire, the answer could be formulated three ways: yes, no, without opinion.

The greater the number of "yes" answers, the more the synthesis was considered positive by the Training Center. The synthesis analysis included N_{TC}=83 contributions of trainees attending the training sessions in 2015; they were represented by all positions of Operations teams.
The results (summarized in table 1) indicate 90.6% "yes", 3.0% "no": overall, the results of the questionnaire provided a positive rating of the 2015 course: 0.86. This average score was calculated by assigning 1 for each answer "yes", –1 for "no" and 0 otherwise. The major contributions to this positive estimate came from questions 5 and 6. The major contributions reducing this positive estimate came from questions 8, 7 and 2.

Table 1: Assessment of the 2015 CLIG sessions using the Training Center questionnaire

CLIG sessions	subjects number N_{TC}	yes (%)	no (%)	average score (*)
2015	83	90.6	3.0	0.86

(*)A fully positive (resp. negative) assessment would give an average score equal to 1 (resp. –1).

As the conclusions of this synthesis (positive assessment) had been found in contradiction with the Operations department management and the trainees' oral feedback (negative perception), it was assumed there was bias regarding the questionnaire or due to the protocol applied. Another questionnaire (hereinafter called the "CLIG research questionnaire") was developed in the frame of the present research and sent to the Operations teams attending the 2015 sessions. Operations pilots and field workers were asked to send it back to the PhD researcher anonymously. The respective survey results were then compared.

The CLIG research questionnaire was launched in June 2016 for two months (not in 2015 due to the delay in management decisions as mentioned in section III-2-2). Eighty participants to the 2015 sessions (pilots or field workers) were sent the paper questionnaire. It was decided to focus on these two positions because the training program addressed these professions and to a lesser extent the managers (see above).

The CLIG research questionnaire suggested the following statements:
1-during the CLIG session, contributions on the referential are useful in my daily activity
2-during the CLIG session, the sequence of preparation of the activity in the classroom is relevant
3-during the CLIG session, the sequence of presentation of the operating feedback in the classroom is adapted
4-during the CLIG session, the sequence working the technical gesture is useful
5- the CLIG session on the overall is useful for my daily activity
6 - Check the following list of adjectives and expressions in those characterizing the whole training session
Statements 1 to 5 were assessed by the trainees on a Likert scale:
□ Strongly disagree □ Disagree □ Neither agree nor disagree □ Agree □ Strongly agree

Statement 6 suggested 6 options (several could be ticked):

- boring
- useless
- disconnected from my profession
- linked with my profession
- instructive
- interesting

For the 2015 CLIG sessions, 50.0% of field workers (22 out of 44) and 13.9% of pilots (5 out of 36) replied, overall 33.7% of respondents (N_R=27) which is a normal participation for this type of survey. For quantitative analysis purposes, responses on a Likert scale have been coded from –2 (strongly disagree) to +2 (strongly agree). An average score per profession and per statement was taken into account. The expected scores per statement should be between 1 and 2 for a session assessed as being satisfactory.

This gave an insight of the overall performance perceived by a profession and indicated the weaknesses per domain.

For field workers, the results for statements 1 to 5 provided a score between 0 and 0.41 except for question 3 (operating feedback) with 0.71 (Fig 1). For the pilots, the results to questions 1 to 5 provided a score between 0 and 0.60 the maximum being for question 2 (preparing activity in the classroom) (Fig 1). The overall mean scores per profession are summarized in table 2.

Table 2: Overall assessment of the 2015 CLIG sessions using the CLIG research questionnaire

CLIG sessions	subjects number N_R	average score (*) (field workers)	average score (*) (pilots)	average score (*) (all)
2015	27	0.29	0.24	0.27

(*)A fully positive (resp. negative) assessment would give an average score equal to 2 (resp. –2).

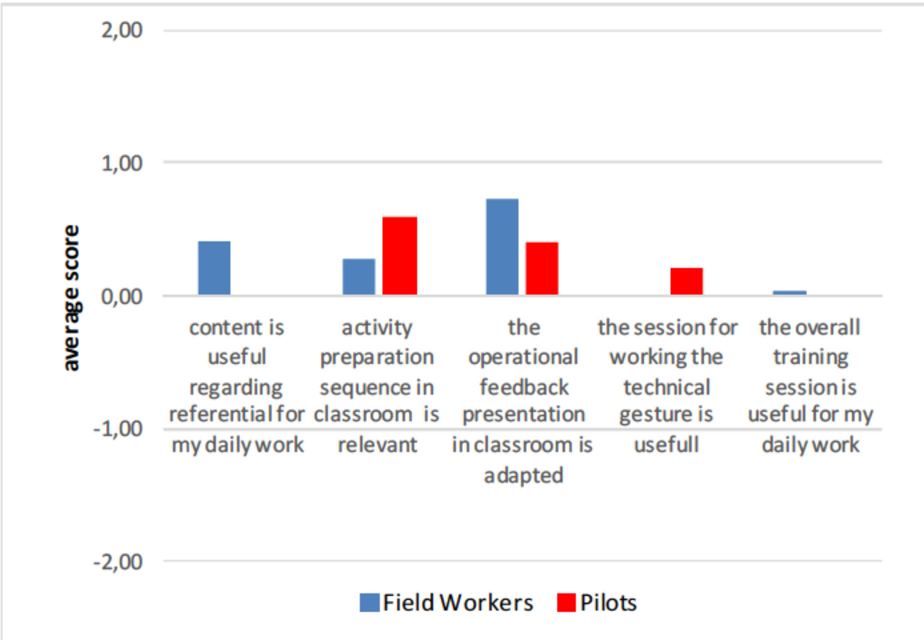

Fig. 1: Average scores per statement for each profession (field worker and pilot) obtained when responding the CLIG research questionnaire about the 2015 CLIG sessions, statements #1 to #5.

The scores obtained per statement being between 0 and 1 and most of them closer to 0 than 1, the conclusion is that the sessions were perceived unsatisfactory.

The characterization by adjectives (Fig. 2) indicated a close perception by the two positions: correlation coefficient regarding the number of subjects per adjective for each profession was r=0.85 (p<0.016) and slope of the fit line was 0.85[32]) with Fcrit(1,10) = 10.0 with a significance of 0.01 and presently F = 1.00 << 10.0 implying that the null hypothesis of similarity for the distributions should not to be rejected at 1% significance level). About half the subjects judged the training session as boring (close to 40%) and a small proportion judged it instructive or interesting (less than 10%).

[32] A comparison through $\chi 2$ –test was not possible due to values equal to zero in both distributions:

$$\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}}$$

where $O_{i,j}$ are observed values and $E_{i,j}$ are expected values.

Although the session was perceived as being in relation with the profession by half the trainees (around 50%), it was however perceived as disconnected from the profession by 25%. This choice was exclusive (disconnected or linked but not both).

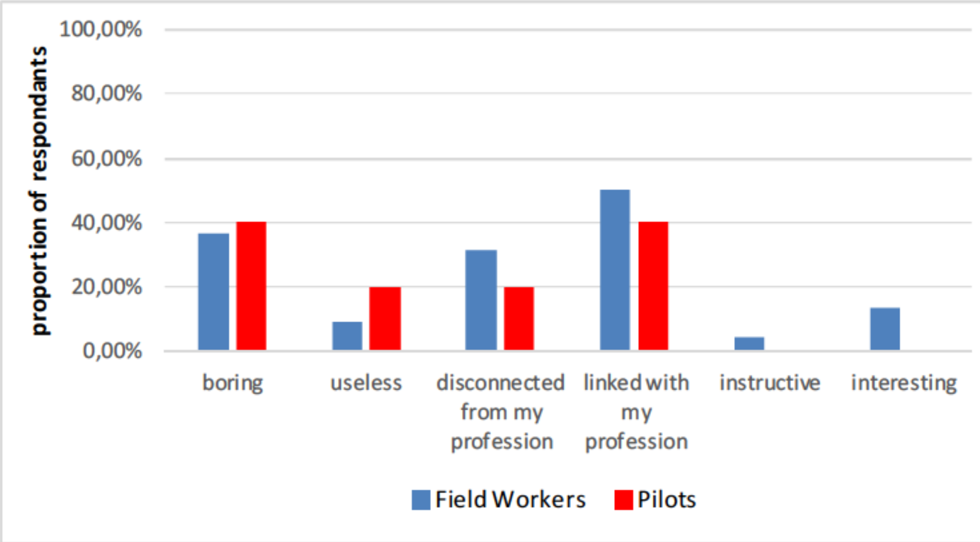

Fig. 2: Characterization of the 2015 CLIG sessions by adjectives for each profession (field worker and pilot) obtained when responding the CLIG research questionnaire, question #6.

Overall, the CLIG research questionnaire confirmed the perception of Operations department management: the trainees' assessment of the session was negative. According to the results of the questionnaire, the 2015 CLIG session would have to be improved in the following aspects:

- the sequences of simulated work activity proposed,
- its overall content to be connected with the daily activities of Operations shift teams,
- probably the way some of the items were presented to the trainees and the associated content in order to make it useful for trainees.

In addition, free answers in the CLIG research questionnaires as well as discussions with Operations workers indicated that scenario should be improved; indeed the activities proposed in SimS were perceived too far from the ROS:

- by their content (operative dimension: that was given to work (activities and operational documentation) was not this of the daily work of the field workers) and this content tended to focus on RP rather than on hydraulic configuration,
- by the simulator itself (figurative dimension: equipment and environment were too far from the ROS),
- by difficulties included in the scenarii ("working the reliability practices with stupid traps is infantilizing without interest and infuriating" according to a field worker and reformulated by many others).

The disconnection of the operative dimension could be induced by several factors:

- the trainees' desire to reconstitute the technical gestures of the field workers on the field simulator: this was not possible for all the equipment and when possible, this had no interest due to the size of the equipment (figurative dimension);
- the emptiness of the pilots and managers' activities: as they were concerned only by parts of the scenarii, some phases of the simulation sequences implying to wait could be boring,
- the exaggerated focus on RP during the simulated activities which had likely transformed the hydraulic configuration work with the help of RP into RP work with hydraulic configuration as a pretext.

III-Assessment of the 2016 CLIG sessions

Applying the CLIG Training center questionnaire, the results (summarized in table 4) indicate 95.5% “yes” (for 90.6% in 2015), 2.2% “no” (for 3.0% in 2015): overall, the results of the questionnaire provided a positive rating of the 2016 course: 0.93 (for 0.88 in 2015). The major contributions reducing this positive estimate came from questions 7 (documents).

Table 4: Assessment of the 2015 CLIG sessions using the Training Center questionnaire

CLIG sessions	subjects number $N_{SimS/HC}$	yes (%)	no (%)	average score (*)
2016	15	95.6	2.2	0.93

(*)A fully positive (resp. negative) assessment would give an average score equal to 1 (resp. –1).

Regarding the CLIG research questionnaire, statements were added in order to take into account the decontextualization and contextualization contributions:
4b-During the CLIG session, the decontextualized simulation sequence is useful.
4c-During the CLIG session, the debriefing sequence of the decontextualized simulation is useful.
4d-During the CLIG session, the filed simulation sequence on Chantier Ecole is useful.
4e-During the session CLIG, the debriefing sequence of the filed simulation on Chantier Ecole is useful.

For field workers, the results for statements 1 to 4a and 5 (same questionnaire than for the 2015 CLIG session) provided a score between 1 and 2 except for question 4a (technical gesture). For the pilots, these statements provided a score between 1 and 2 except for 1 and 4a (referential and technical gesture) (Fig 6). The overall mean scores per profession are summarized in table 5.

Fig. 6 also shows the assessment of a national expert: this person was invited to watch the second session as he was in charge of advising the national level management of the company regarding training of the Operations teams. He was asked to fill in the CLIG research questionnaire at the end of the one-day session and his assessment is here published with his agreement.

Table 5: Overall assessment of the 2015 CLIG sessions using the research questionnaire

CLIG sessions	number of subjects $N_{SimS/HC}$	average score (*) (field workers)	average score (*) (pilots)	average score (*) (with managers)	average score (*) (without managers)
2016 st. 1 to 4a & 5	15	1.28	0.93	1.14	0.96
2016 all statements	15	1.25	1.07	1.16	1.12

(*)A fully positive (resp. negative) assessment would give an average score equal to 2 (resp. –2).

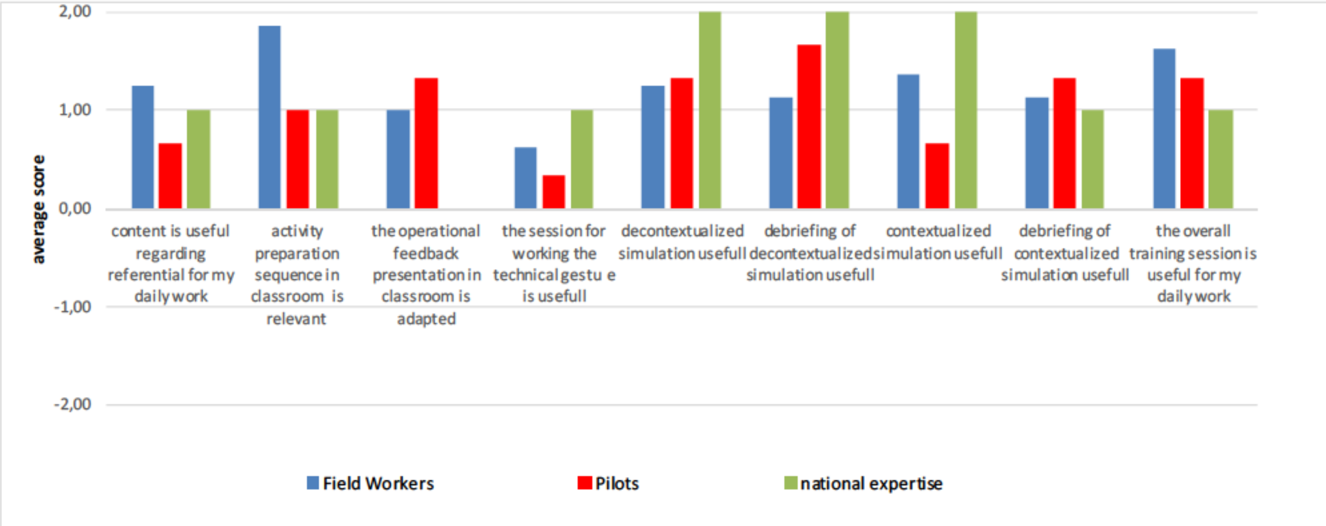

Fig. 6: Average scores per statement for each profession (field worker and pilot) obtained when responding the CLIG research questionnaire.

The characterization by adjectives (Fig. 7) indicated a close perception by the two positions: correlation coefficient regarding the number of subjects per adjective for each profession was r=0.99 (p<0.0001) when withdrawing the item "instructive" and slope of the fit line was 0.66[33]) with Fcrit(1,16) = 8.53 with a significance of 0.01 and presently F = 1.00 << 8.53 implying that the null hypothesis of similarity for the distributions should not to be rejected at 1% significance level). None of the subjects judged the training session with negative adjectives and a large proportion judged it interesting (up to 85% for field workers). The session was perceived as being in relation with the profession by half the trainees and none of them perceived it as disconnected from the profession.

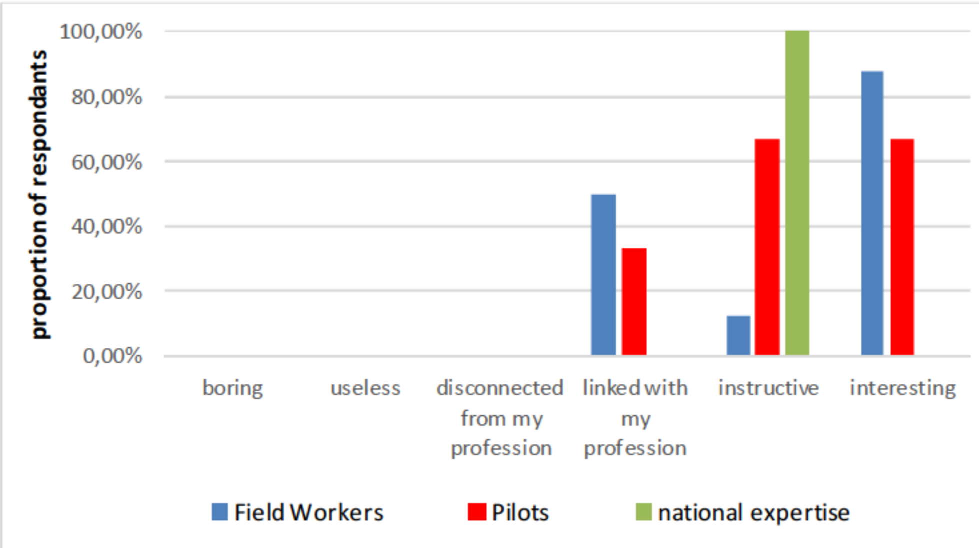

Fig. 7: Characterization of the 2016 CLIG sessions by adjectives for each profession (field worker and pilot) and form the national expert's standpoint obtained when responding the CLIG research questionnaire, question #6.

The national expert sent a short written report one day after the second session. He noticed that "the trainees were satisfied with this experimental session, specifying that this method of setting up a situation in decontextualized environment enabled them to cooperate better and collaborate together". He added that, in his opinion, "the pedagogical workshop in decontextualized environment brings an added value on the reflection that the trainees have on the organization, the method and

[33] A comparison through X2 –test was not possible due to values equal to zero in both distributions.

the structure for the repairing and the realization of an activity" and "scenarios in decontextualized environment (surgical and aviation) and known environment [field simulator] adds complement to the collaborative method of an activity". Figures 6 and 7 illustrate his positive assessment in green.