

1 **Original Research Article**
2 **Subjective Ethnographic Protocol for Work**
3 **Activity Analysis and Occupational Training**
4 **Improvement**

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7
8 **ABSTRACT**
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The renewal of the staff in companies, with no possibilities sometimes for the newcomers to meet experienced workers already retired, is considered by some analysts as a “skills drain”. In such a context, improving the occupational training program is a crucial challenge. The method presented here aims at providing an in-depth analysis of what makes the competencies of experience workers in order to provide more exhaustive input data for training. This might contribute to lessen the aforementioned problem. It uses subjective video recordings of work activities and applies co-analysis (researcher-worker) based on the Square of Perceived Action model developed for the purpose in the frame of Activity Theory. The Square of Perceived Action-based method showed a better efficiency when compared with three other methods for four different activities. It also showed a good acceptance by the professionals who felt an improvement of their vocational practices after having being involved in such an analysis of their work activity.

10
11 Keywords: Activity analysis; Activity Theory; Video; Vocational training; Competencies; Skills;
12 Knowledge; High Risk Industry
13

14 **1. INTRODUCTION**
15

16 Most long established French firms such as Electricité de France (EDF), and particularly
17 Chinon Nuclear Power Plant (NPP), are subject to a high renewal of employees. For a plant
18 Chinon NPP which has 1200 employees (all professions included), in the next ten-fifteen
19 years, 33% of population will be renewed and, currently, 50% of the staff will be renewed in
20 the next 5 years. Young employees already represent 13% of the staff. This “exodus” is
21 considered by some as a “skills drain”.
22

23 In parallel, companionship and tutoring are getting less and less effective over time, not
24 through any desire of the experienced workers, but due to the time left for such a mission:
25 the workers explain that their workload is increasing while the teams become smaller. In this
26 context, training as in practice or repetition becomes crucial in professional training.

27 We do need to improve identification of what must be taken from experienced workers in real
28 operating situations with the objective to input innovative data into the training program. For
29 this aim, we need to go deeply inside the work activity than what is done to date in the
30 company. The challenge is to be both relevant (innovation) and efficient (fast results:
31 developing a method which would imply several weeks of analysis per activity would not
32 solve the problem as work activities concerned by this need are numerous).
33

34 The method used in the present approach was based on Le Bellu's work [1], [2] which
35 showed its performance addressing a nearby case to the present study. Her method was
36 based on miniature camera mounted on helmet for subjective video recordings combined to
37 simultaneous and situated verbalization and analyzed through a protocol based on

Subjective Evidence-Based Ethnography or SEBE [3] and Perceived Quality Theory [4]-[6]. Video analysis was chosen for the study because, as noticed by others, it contributes to a great extent to 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” [7]. However Le Bellu’s protocol had to be adapted: the differences lied mainly in the object studied (professional gestures for Le Bellu vs whole activity in context for the present study), in the number of subjects (individual activity vs individual or collaborative activity) and in the working context (fully controlled vs naturalistic). Experiments and applications were undertaken at Chinon NPP.

2. MATERIAL AND METHODS

2.1. Design

Phase 1 consisted first in clarifying the nature of what was relevant to be identified in the work activity to access what makes the skills and competencies of workers.

Phase 2 consisted in adapting Le Bellu's protocol [1] for data analysis in replay interview. In parallel, the adaptation the equipment was rather easy (see section "Apparatus").

Phase 3 was devoted to testing the designed protocol obtained in phase 2. Different activities of workers involved in the operation of nuclear reactor were chosen. The work situations were analyzed both on full scale simulators and in real operating situations.

Work activities chosen were:

- Individual setting of a neutral point on a pneumatic actuator of valve SEREG: the worker had to handle the actuator of a valve and to measure its displacement in order to identify the position of a neutral point and set it to optimize the functioning of the associated valve.
- Individual setting of cams of a valve actuator: position of the cams had to be adjusted for optimizing the functioning.
- Collaborative hydraulic configuration of the circuit REA: a field worker and a reactor pilot had to work together in order to configure a part of a circuit called REA according to a given procedure.
- Collaborative implementation of the control-command curve G3 of the reactor during test EP-RGL-4: two testing technicians had to carry out measurements in the control-command system with the help of a reactor pilot moving the control rods of the nuclear core according to the test need, and then to implement new values inside the control-command system.

Activities were analyzed in this order. The first three ones were performed on a full scale simulator to assess risks for the workers and the industrial process induced by the equipment used for video recordings. The fourth one was undertaken in real operating situation. The two first activities were chosen because they were similar, short and easy to be performed on simulator. They were performed by the same worker and analyzed applying two methods: self-confrontation and our developed method. This repetition was necessary to assess the potential primacy effect due to the fact that the subject had to analyze twice his activity (one per method), the second analysis being potentially favored by the realization of the first one. Therefore, the subject performed the first activity, co-performed the self-confrontation analysis with an experienced trainer and later undertook the SEBE analysis

with the researcher, and a month after the subject performed the second activity, co-performed the SEBE analysis and later the self-confrontation analysis. For the other activities, the methods compared to the SEBE analysis were undertaken by other teams of analysts and workers: they are described in section "Procedure".

Assessment of the methods' efficiency was done according to criteria presented in section "Procedure".

2.2. Apparatus

Due to recent technical progress, the size of the SEBE metrology equipment could be reduced compared to what Le Bellu [1] used in her experiments, therefore lowering the probability of interaction with the industrial environment in real operating situations. It was made up of three parts linked with cables: i) a micro audio digital recorder DVR-500-HD2 self powered by internal batteries, not much bigger than a mobile phone, ii) a 4 mm diameter - 40 mm length miniaturized subcam mounted on safety glasses, iii) a lavalier microphone. This SEBE equipment was purchased at Active Media Concept. This equipment fulfilled the requirements of video quality, energy autonomy, data storage and size.

2.3. Procedure

2.3.1 Phase 1 – Nature of what makes the skills and competencies of workers

This consisted in clarifying terms such as skills and competencies and their interaction with knowledge and know-how. This preliminary analysis appeared necessary first due to controversies noticed in the literature and second due to possible misunderstandings between Francophone, Anglophone and east-European meanings of these terms. For this aim, the literature of these three scientific communities were considered and compared. The final result sought was not to obtain the absolute true definitions for these terms but to elaborate clear definitions adapted for this study.

2.3.2 Phase 2 – Adapting Le Bellu's protocol

This consisted in an analysis to adapt Le Bellu's protocol for interview [1] in order to preserve the character "naturalistic" of the activity (no repeated fully controlled situations, no simultaneous verbalization). The new protocol could be only elaborated upon a suitable model allowing us to analyze activity of a given worker in operating situation observed just once. Hence, a bibliographic research examined and selected the models available in the literature. Phase 2 resulted in the design of an adapted protocol for data acquisition and analysis.

2.3.3 Phase 3 – Testing the protocol obtained in phase 2

Phase 3 was testing the designed protocol and SEBE equipment selected in phase 2. For each activity, the analysis was carried out in two ways: one applying the SEBE protocol developed in phase 2, and one based on a method used in the company and widely used elsewhere. Then a comparison was done regarding two kinds of criteria: performance and efficiency. The performance criteria reflected the degree of depth reached to describe what make the skills and competencies of workers (the protocol outcomes); the efficiency criteria reflected the time and the resource needed to obtain the protocol outcomes. In addition, implementation criteria were considered, inherent to the SEBE equipment (e.g. negotiation

with the management to undertake the investigation, installation of video devices and capture of the raw activity, obtaining subjects' informed consent) and to the SEBE interview (e.g. subjects' spontaneous participation).

Table 1 presents the four activities chosen for the test in the first column. For each one, the next columns precise where the activities were performed, the method which was used for activity analysis and compared with SEBE method and analysts' characteristics. The methods compared to the SEBE method were: self-confrontation, SAT-based method and description-based method.

Table 1. Specifications of the work situations used for comparative analysis

Activity (reference)	Location of the activity	Compared analysis Method	Analysts' characteristics
setting of a neutral point on a pneumatic actuator of valve (individual activity) Duration: 10 min. (TEST-IND-ROB-C1)	Full scale valve & tap simulator	self-confrontation	Simulator Trainer: Gender: male Age range: 41-50 yo. Duration in the position: 3 y.
setting of cams of a valve actuator (individual activity) Duration: 10 min. (TEST-IND-ROB-C2)	idem	idem	idem
hydraulic configuration of the circuit REA (collaborative activity) Duration: 60 min. (TEST-COLL-OP-AGT 01)	Full scale simulators (control room and industrial field)	SAT-based method	National Training dept.
implementation of the control-command curve G3 of the reactor during test EP-RGL-4 (collaborative activity) Duration: 360 min. (ROS-COLL-OP-TT 01)	Real operating premises	SAT + Description-based method	Training Center of Chinon with the help of managers of the Testing dept.

The self-confrontation was developed by Von Cranach [8], and later by Theureau [9] as a method of investigation of human activity through inter-dependent levels of action: the basis is the recovery of the ongoing subject's behavior through audio-video recordings, the recovery of the cognitive level guiding action by a self-confrontation of the subject to these recordings during interview. Self-confrontation is thus a deferred examination of the dynamics of structural coupling subject-situation supported jointly by means of reproduction of the behavior (e.g., video) and by the analyst as both observer and interlocutor [9].

The SAT method was elaborated as a Systematic Approach to Training developed in 1996 by the International Atomic Energy Agency [10], [11]. This was applied by the national training dept. of the company in order to identify what had to be taught in training sessions regarding each activity of each profession: professionals of the industrial trade and professionals of the training program met together and worked for several hours first to identify the activities related to a profession and second for each activity to identify i) pedagogical units (knowledge and know-how) to be acquired by trainees and ii) associated training units (available already in training programs or to be developed). This deployment then involved 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 of several days spending about half an hour per activity. The NPP fleet including 20 sites, for a complete achievement of the process, this resulted at least in a 2.2 to 4.4 man.day cost $((5 \text{ to } 10) \times (20+1) \times (1/2)/24)$; integration of local feedbacks were not quantified. In case of need of additional analysis for specific training adaptation regarding a difficult activity, this could lead to an additional day of analysis with 4 persons increasing the cost to 6.2 to 8.4 man.day.

The description-based method consisted in sharing between trainers and technical experts of the trade what must be taught for a given activity according to their own work experience. From this exchange, trainers were in charge of writing pedagogical specifications for the design of the training session and they submitted it for critics, advice and complements to the technical experts.

2.4. Subjects

Subjects were selected according to their professional experience (Table 2). Preliminary, their managers were met to obtain an agreement and then subjects were presented the method and the goal: their participation was voluntary and they signed an informed consent form knowing that all data would be used anonymously.

Table 2. Subjects' characteristics involved in situations used for comparative analysis

Activity (reference)	Subject #1's characteristics	Subject #2's characteristics
setting of a neutral point on a pneumatic actuator of valve (individual activity) Duration: 10 min. (TEST-IND-ROB-C1)	Simulator Trainer: Gender: male Age range: 41-50 yo. Duration in the position: 3 y.	none
setting of cams of a valve actuator (individual activity) Duration: 10 min. (TEST-IND-ROB-C2)	idem	none
hydraulic configuration of the circuit REA (collaborative activity) Duration: 60 min. (TEST-COLL-OP-AGT 01)	Experienced pilot: Gender: male Age range: 41-50 yo. Duration in the position: 13 y.	Field worker: Gender: male Age range: 21-30 yo. Duration in the position: 3 y.
implementation of the control-command curve G3 of the reactor during test EP-RGL-4 (collaborative activity) Duration: 360 min. (ROS-COLL-OP-TT 01)	Experienced Testing technician: Gender: male Age range: 40-51 yo. Duration in the: 15 y.	Testing technician: Gender: male Age range: 21-30 yo. Duration in the position: 3 y.

3. RESULTS

3.1. Phase 1 – Nature of what makes the skills and competencies of workers

The aim of the protocol developed in the present study was to determine what makes up the skills and competencies of experienced workers in a refined and efficient manner. For this

study to be quite clear, it was firstly necessary to define skills and competencies as the difference between them did not initially appear obvious when first looking at the scientific literature [12]–[45].

From this literature the main points of importance for the present study are summarized thereafter.

On the basis of a guideline [40] provided by the Northwestern University (USA) in 2004, Peregrin [41] reminded us that competencies could be seen as describing the skills, knowledge and behavior 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 [42]). Knowledge would be linked with areas of specialty or expertise; for example, nursing, finance, employment law, or history. Behavior would be linked with characteristics an employee must display in the job; for instance, initiative, collegiality, resourcefulness or professionalism.

These concepts cannot be separated from action: Talyzina [43] 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 the subject elaborating know-how from knowledge.

Therefore, our research focused on knowledge in action to identify what makes workers’ competencies. The literature analysis highlighted another important characteristic: the spontaneity of the activity had to preserve as much as possible to ensure access to tacit knowledge in situation: for Polanyi [22], tacit knowledge is intuitive and spontaneous [44] and at the collective level, it proceeds the improvisation that summons the group of individuals in context [45].

3.2. Phase 2 – Adapting Le Bellu’s protocol

Le Bellu’s work lied on Activity Theory and Perceived Quality Theory well adapted to structure the simultaneous verbalization and gestures analysis.

In the present study, we aimed at capturing and analyzing spontaneous activities (not only gestures) in industrial environment. It was better to structure the interview and the analysis upon a model of action, even upon a model involving competencies and action.

Exploring literature in order to find a model linking competencies and action in activity, one approach consisted in looking for models of action, and another one for models of competencies. Surprisingly, very few models were available in literature from either side.

Regarding models of actions, the model of Searle [46] was derived of the model of Davidson [47], 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. Searle added the notions of rationality and free will before action and adjustment during action. None of them consider competencies related to action.

Gollwitzer [48] suggested a model of “action phases” with four different consecutive action phases of goal pursuit: the predecisional phase, the preactional phase, the actional phase, and the postactional phase [48]–[50]. The model suggested a comprehensive temporal perspective on the course of action and did not make link with competencies; it mainly dealt with goal intention and implementation intention.

252 The models of situated action [51]-[54] presented action as responses to the environment
 253 and the related goals as retrofitting constructions of the subject compared to the activity
 254 carried out. In this context, the subject does not develop the goals of the action. The action
 255 itself is therefore a reaction to the situation lived rather than an action in a situation. These
 256 models can hardly fit the theoretical frame chosen for the present work, the Activity Theory
 257 [55],[56] within which we consider competencies coming through actions and being achieved
 258 within an activity situation, determined by intentions, goals and context.

259 The TOTE model suggested by Miller et al.[57] was innovative in that the authors were first
 260 modeling the contribution of mediating vectors between stimulus and response in action.
 261 They described action as successive steps and feedback within a progressive structure: Test
 262 – Operate – Test – Exit. Yet the action is thus restricted to a limitative cognitive process
 263 which does not relate to competencies and remains far from the notion of activity.

264 The same for the model of planned action [58], [59] introducing the cognitive intentional
 265 dimension of action, as well as for Von Cranach's work [60]: the action was conceived as an
 266 intentional sequence linking action and representation in a complex relationship with long
 267 term considerations.

268
 269 Regarding general models of competencies (as opposed to specific competencies models
 270 dealing for example with reading or leadership), the well-known Dreyfus's skills model [61] is
 271 limited to a suggestion of different steps characterizing the subject's levels of competencies
 272 with no explicit link to action.

273 The revised Bloom's taxonomy [62], [63], approaching skills and competencies according to
 274 a classification of learning objectives into three domains (cognitive, affective, psychomotor)
 275 makes a link with action by introducing action verbs (analyzed in depth by many
 276 researchers; e.g. [64]) related to each categories; however, this approach, devoted to a
 277 mental activity, remains far from the notion of activity, and cannot easily address our
 278 concern.

279
 280 The motor skills model of Argyle & Kendon [65] was elaborated to explain social interactions
 281 considering that social skills operate much like a serial skills motor. The model assumes
 282 subjects' motivation is sustained by goals which are achieved through a systematic and
 283 progressive loop adjusted by a perceived (perceptive capacities) and integrated (translation)
 284 feedback in order to respond to the outcomes of previous actions. This model is interesting
 285 in that it considers competencies coming through actions (the feedback loop) and being
 286 achieved within an activity situation, determined by intentions and goals and context. The
 287 weakness of this model lies in a lack of descriptive relationships between competencies and
 288 action incorporated into the words "translation" and "feedback".

289
 290 The last model found in literature is the one proposed by Le Boterf [66] regarding
 291 competencies at work, explicitly associated with work activity. The model relates to action by
 292 the way Le Boterf depicted competencies at work involving action through the verb "to act",
 293 "agir" in French. He defined competencies as a system of three poles: in French, "Savoir
 294 agir", "Vouloir agir", "Pouvoir agir". Valdes Conca & de Juana-Espinosa [67] as other authors
 295 referring to Le Boterf's French work, translated as the interaction of three poles: Knowing
 296 how to act, Wanting to act, Being able to act. This includes a mistake in the translation; the
 297 right meaning is: Knowing to act, Wanting to act, Being able to act. We shall argue this point
 298 soon.

299
 300 The model defines thus competencies as an interacting system of three poles, drawing
 301 competencies as a triangle (Figure 1). Knowing to act is that the professional will know to
 302 implement in situation, whether planned or unexpected, provided that it is within the bounds

of the profession; this is the practical implementation of know-how, knowledge, all personal endogenous professional resources which combine themselves in knowing to act in situation. 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 social conditions that make it possible and legitimate responsibility and risk-taking of the professional) and endogenous resources (subjects' capacities).

Le Boterf's model therefore suggested already 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 [68], "competencies are manifest in the interaction of a subject (or a group) with a task in a given situation".

The question is here to determine what is missing to skip this model into the description of action. Referring to the Activity Theory, it is necessary to refer to the motives and goals in order to transform this model for action. This means that a fourth pole is expected in terms of Having to act. Hence the triangle of competencies changes into the square action of the subject, even more precisely the square of perceived action (Figure 1). In the square of perceived action (SPEAC), Having to act is mainly shaped by the organization, driven by the order (client, manager) and by the definition of the task.

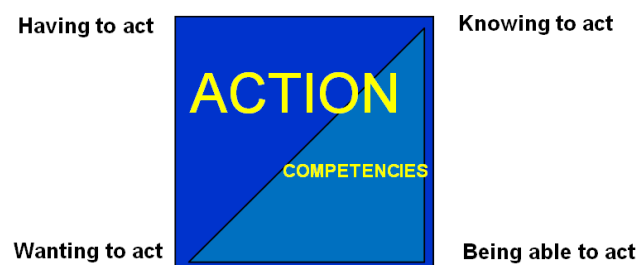


Fig. 1. The square of perceived action model (SPEAC model)

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 interpolational relationships: there are three within a triangle and six within a square: the side relationships and the diagonal relationships.

The model was applied to describe actions regarding 50 different work activities, individual or collective, with success and was thus validated.

The SPEAC model was therefore used by applying a pole-based protocol of analysis through the interview. To do so, we considered each pole of the SPEAC model and integrated questions in the 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 in [2]). 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 do you have to do? / What do not you have to do?

- 344 • Pole Knowing to act for the questions:
345 What do you know to do? / What do not you know to do?
- 346 • Pole Wanting to act for the questions:
347 What did you want to do? / What did not you want to do?
- 348 • Pole Being able to act for the questions:
349 What were you able to do? / What were not you able to do? (in terms of means, not
350 related to the knowledge).

351

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

359

360 Therefore, during the interview, it is interesting to question these two poles before watching
361 the subjective video so that viewing the video does not influence the content of the answers:
362 the subject is positioned as in the operating situation, void of a new exposure to the
363 situation.

364

365 On the contrary the poles Wanting to act and Being able to act may be thought by the worker
366 before performing the activity, but they may be continuously and significantly adjusted to the
367 situation while performing the activity. These poles are less pre-defined by the organization
368 than the two others. For the subjective video to remind the worker how performing the
369 activity influenced the poles Wanting to act and Being able to act, they are questioned after
370 the viewing in the frame of the interview.

371

372 Based on the SPEAC model, the structure of the interview is therefore designed as follow:

- 373 • Before watching the subjective video, the two poles Having to act and Knowing to
374 act are questioned.
- 375 • A subjective re-situ interview is performed watching the subjective video.
- 376 • After watching the subjective video, the two poles Wanting to act and Being able to
377 act are questioned.

378

379 The structure of the SEBE/SPEAC-based interview offers subsequently an interesting
380 possibility: on one hand by analyzing the difference between answers to questions from one
381 another, and on the other hand by analyzing the difference between answers to questions
382 and the resulting content of the subjective re-situ interview, the analyst can identify potential
383 tacit knowledge and differentiate it from explicit knowledge.

384

385 The developed protocol integrated the above considerations of phase 1: applied to work
386 activities with a minimum preparation of the subjects in order not to decrease the spontaneity
387 of the realization and favor access to tacit knowledge in situations; no anticipated or
388 simultaneous verbalization was required.

389 The protocol was structured in four phases: preparation phase, capture phase, analysis
390 phase, validation.

391

392 **Preparation phase:** This was to identify when the activity would take place and the
393 corresponding work situation and to negotiate with the management to obtain the agreement
394 to carry out the study. When the agreement was obtained, the management gave short

395 explanation to the potential participants.

396

397 **Capture phase:** This was a direct contact with the participants: informing participants and
398 obtaining informed consent about the capture phase, installing external and subjective video
399 devices, framing, capturing the naturalistic activity, storing material and providing immediate
400 feedback, and finally making appointments for the interview.

401

402 **Analysis phase:** This was a pre-view of the recordings without participants and selection by
403 the researcher of particular sequences of the video for subjects to comment on them,
404 interview sequences with participants, post-analysis of this interview by the researcher.

405

406 **Validation:** This was sharing the findings of the post-analysis with the participants, helping
407 the researcher to validate the conclusions, helping participants to have feedback about their
408 knowledge and know-how as tacit, explicit, individual or collective.

409

410 **3.3. Phase 3 – Testing the protocol obtained in phase 2**

411

412 The implementation criteria inherent to the SEBE equipment were all satisfactory for the four
413 activities. Subjects' feelings including the disturbance were discussed and no special
414 problem was noticed or reported. A risk assessment was undertaken before the real
415 operating work situation [69].

416

417 Subjects' spontaneous participation was observed in all SEBE/SPEAC interviews, satisfying
418 therefore the implementation criterion inherent to SEBE interview. This seemed being
419 favored especially by the relative position researcher/subject in front of the screen whilst
420 viewing the videos (the screen was between them, not in front of one of them) and subjects
421 were engaged to stop and restart the video according to what they wanted to comment or
422 answer or show and were given the computer mouse in the hand at the beginning of the
423 viewing. These findings were obtained by comparing the interviews recordings in the two first
424 conditions; other methods of the two last configurations were not concerned by video.

425

426 The values of performance criteria elaborated according to the findings in phases 1 and 2
427 are summarized in Table 3. The first column reminds the activity which the comparison
428 addresses, the second column reminds the method compared to the SEBE/SPEAC method,
429 other boxes give ratios of the criteria. Regarding performance ratios, a value greater than 1
430 illustrates a higher performance of the SEBE/SPEAC method; when the denominator is null,
431 the ratio is detailed. Regarding efficiency ratios, a value greater than 1 illustrates a lower
432 performance of the SEBE/SPEAC method.

433

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

439

440 **Table 3. Ratios of performance and efficiency criteria of the methods applied per**
441 **activities**

442

Activity (reference)	Analysis Method	individual knowledge	collective knowledge	tacit knowledge identification	time spent for acquisition-analysis (days)	product (Men.Days)
setting of a neutral point on a pneumatic actuator of valve (individual activity)	self-confrontation	1.75	3.00	Y/N	1.00	1.00
setting of cams of a valve actuator (individual activity)	idem	1.45	3.00	Y/N	1.00	1.00
hydraulic configuration of the circuit REA (collaborative activity)	SAT-based method	9.00	13/0	Y/N	1.00	0.75
implementation of the control-command curve G3 of the reactor during test EP-RGL-4 (collaborative activity)	SAT + Description-based method	3.00	5/0	Y/N	96.00	0.65

4. DISCUSSION

4.1. Implementation

It may be surprising that implementation criteria were all satisfactory and that no particular problem was encountered. Especially, negotiation and appointment scheduling were rather easy. This might be put to the account of previous existing relationship between the researcher and the participants (by having working together beforehand in other work analysis contexts) combined to the fact that both researcher and participants were employed by the same company. In case of hesitation to participate, what made the participant changing her/his mind was: i) a longer explanation of the motivation and the objectives of the research, including the presentation of the benefits for the participant(s), the colleagues and the company in terms of training efficiency and work performance improvement, ii) a detailed presentation of ethics protecting participants' interests, iii) the written engagement (informed consent form) co-signed by the participant and the researcher guarantying the anonymous use of the data including the prohibition to use the film by anybody else than the researcher in private research conditions except in case of written agreement of the participants.

4.2. Efficiency

The SEBE/SPEAC method was successfully compared to three other methods of work analysis in four configurations showing a better identification of knowledge. Table 3 gives a quantified account of the SEBE/SPEAC method advantage: higher number of knowledge identified, access to tacit knowledge, lower cost. When comparing the methods, the better efficiency of the SEBE/SPEAC method appeared to be due to a combination of the naturalistic context of the observed activity, the interview involving participants in the review of their actions and the inter-comparison of answers favored by the questioning structure.

4.3. Avoided trajectories

The SPEAC-based structure of the questionnaire applied during the interview also showed its capacity to highlight avoided trajectories towards the goals. A fragment of transcription is presented hereafter adopting the widely used orthography developed by Gail Jefferson as suggested by Hindmarsh & Heath [70] for similar research on video analysis; further details are available in [71] Atkinson and Heritage and a short overview of the orthography is given in appendix.

This example concerned the field worker handling valves during hydraulic configuration.

Fragment 1 Subject =S; Researcher=R

1.S: I didn't want to take shortcuts. This is because I was with you and I went through the official ways (.) otherwise I would have climbed over.

2.R: so what you tell me (.) it's because you were with me you took the way that were offi[cial] (.)

3.S: [yes.]

4.R: whi[le]::

5.S: [well sometimes it was easy to climb over and sometimes the valve was just behind I knew

Fragment 1 illustrates how the field worker avoided a physical trajectory which is also an activity trajectory in terms of goal: he could have gone easier and faster doing differently. Fragment 2 transcripts the explanation he gave regarding this choice.

Fragment 2

1.R: and: why the fact to be with me made you use the:: official ways?

2.S: well: because:: (blows = 03.0) well:: well it is not image to show (smile)

3.R: ah okay (02.0) the fact to climb over (.) it presents a: particular risk?

4.S: bah: it can produ=bah: falling: from height thus: it is always an additional risk (.)

He would have been pleased to climb over to shorten the way (save time and physical energy) illustrated by Fragment 1 - utterance 5 (referring to the positive aspect of Wanting to act), but he chose not to do it (referring to the negative aspect of Wanting to act): he did not want to show taking risk (Fragment 2, utterances 3-4) in front of an observer (Fragment 1, utterance 2). This was linked with the negative aspect of pole Having to act. Furthermore, the subject's difficulty to explain (Fragment 2, utterance 2) with blowing and elongated utterances completes the previous finding: what was avoided after self-made choice guided by personal considerations for less cognitive or physical energy spending was difficult to tell because of its conflict between Wanting to act and Having to act. This finding emphasizes here the dynamic dimension of the SPEAC model through the conflict between poles.

4.4. Tacit knowledge

The inter-comparison of answers favored by the questioning structure of the SEBE/SPAEC protocol allowed us to notice that participants did not speak spontaneously of some knowledge. Instead sometimes explaining this omission by an oversight, they said "but it is obvious [to know that]" thus ignoring voluntarily this information. This situation then engaged the researcher to ask whether or not this knowledge was part of the basic knowledge expected for the profession (initial vocational training) and thus not relevant as a knowledge to be taught in a retraining cycle. If so, this was not counted as a tacit knowledge; otherwise, it was considered as probably tacit.

For other methods, no tacit knowledge was identified.

525 **4.5. Side effect**

526

527 Furthermore, subjects' feedback obtained during the validation phase showed that all
528 subjects felt an improvement of their professional practices after having being involved in the
529 SEBE/SPEAC analysis of their activity. This finding was not surprising as this improvement
530 induced by self-confrontation was already noticed elsewhere (e.g. [72]).

531

532 These findings led the head management of Chinon NPP to ask for application of the
533 SEBE/SPEAC method for all the operating teams for training session. The opportunity was
534 taken to ask subjects to fill a questionnaire regarding the assessment of the method. The
535 results available to date confirmed the subjects' feeling of immediate significant
536 improvement.

537

538 **4.6. Risks encountered applying the SEBE/SPEAC method**

539

540 The SEBE equipment was unanimously accepted by subjects. Yet, other experiments [69]
541 showed that precaution had to be taken regarding potential problems induced by the SEBE
542 equipment. Hence a risk assessment is recommended for any type of SEBE methods before
543 application to any real operating situation.

544

545

546 **5. CONCLUSION**

547

548 The results obtained let us conclude that the SEBE/SPEAC protocol integrating the re-situ
549 subjective goal oriented interview is an efficient method to identify knowledge that makes
550 competencies of experienced workers. Compared to three other methods widely used,
551 knowledge identification is more exhaustive (making it a powerful tool that will help
552 industrials to improve their occupational training program) and low cost in terms of time
553 spending and persons working (making it an interesting investment for companies).

554

555 The applications presented here concerned technical activities in industrial contexts
556 exclusively. However we postulate that the method could be similarly applied to any other
557 kind of work activities including managers' activities or office works.

558

559 The main limit of the method resides in the identification of tacit knowledge: according to our
560 findings, any knowledge detected as potentially tacit during the post-analysis stage must be
561 put into discussion with workers in order to validate it as tacit or not. Furthermore, for each
562 identified tacit knowledge, it may be worth to evaluate the necessity to teach it rather than let
563 it be elaborated through professional experience as showed elsewhere [73].

564

565 **CONSENT**

566

567 The author declares that written informed consent was obtained from subjects for publication
568 of this paper. A copy of the written consent is available for review by the Editorial office/Chief
569 Editor/Editorial Board members of this journal.

570

571 **ETHICAL APPROVAL**

572

573 This study received ethical approval of the Ethics Committee of the Dept. of Social
574 Psychology (LSE, London, UK) and has therefore been performed in accordance with the
575 ethical standards laid down in the 1964 Declaration of Helsinki.

576

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