Training design for a proposed job of operating the Remote Monitoring System for Risk Prevention (RMSRP) in French Nuclear Power Plants

Stanislas Couix*, Vincent Boccard*, Isabelle Fucks*

EDF – EDF R&D – Industrial Risk Management Department – Human and Organizational Factors, Clamart, FRANCE; CNRS – Laboratory of Informatics for Mechanics and Engineering Sciences, Orsay, FRANCE

This contribution focuses on a new process to design training for a future and non-observable activity like the one of RMSRP operators. After presenting the industrial context and the limits of the classical training design processes, we describe our new training design approach called SITUAATING (SITUation and Activity bAsed traiNIng desiGn) used during the design of RMSRP operators' training. This approach is innovative for several reasons. Firstly, it's theoretically founded and driven by a theory of the functioning of humans in work situations: the Activity Theory. Secondly, the direct observation and analysis of the work that trainees have to learn, i.e. the future activity, is not needed. Analyses can be performed on an activity that shares similar characteristics with the future activity. Thirdly, we consider that trainers working conditions are the learning conditions of trainees. Our approach aims to take into account the real working conditions of trainers from the first phase of the training design process. Fourthly, SITUAATING is not sequential, it's flexible. Finally, our approach is participative: future trainees, future work activity experts, human factors and ergonomics (HFE) experts, project managers, and technical system experts have to work together to produce training content and a training program taking their specific point of view into account.

Keywords: work analysis, training design process, occupational risk prevention

1 Introduction

In French Nuclear Power Plants (NPP), the safety of workers (EDF employees and contractors’ employees) performing maintenance operations in the controlled area when the reactor is shut down is currently monitored by the workers’ foremen and EDF occupational risk prevention specialists (ORPS). The job of ORPS is to help workers’ foremen to ensure that maintenance workers exposure to radiological and conventional hazards are below tolerated limits. From a risk prevention perspective, maintenance work can be classified according to the workers exposure to hazards: low, medium or high. If workers exposure to hazards is medium or high, an ORPS will be fully dedicated to the monitoring of their exposure. In other cases, ORPS will make regular checks on the maintenance work. In this case, it is difficult for ORPS to detect and correct a hazard issue before the workers’ exposure to hazard reaches the tolerated limits. Thus, occupational risk prevention is often reactive. To help ORPS to be more proactive, and thus, to enhance all the workers’ safety in the controlled area, EDF has designed a new device: the Remote Monitoring System for Risk Prevention (RMSRP).

The RMSRP is situated outside the controlled area. It aggregates wirelessly: various data concerning workers exposure to radiological hazards (irradiation and contamination), and video and audio installed in the controlled area. Using this device, future RMSRP operators will be able to assist remotely and proactively workers and workers’ foremen in order to lower their exposure to conventional and radiological hazards. RMSRP will be used by highly skilled ORPS. Operating this system will be an additional and periodic new mission requiring specific and new competencies (Fucks & Couix, 2014). A training design process\(^1\) has been conducted in order to prepare and train the future RMSRP operators before RMSRP deployment in all the French NPPs. Two prototypes have already been installed. Nonetheless, compared to the future RMSRP, these are not fully functional and have a very different human-machine interface.

Consequently, current RMSRP operators’ activity is different from what it will be. Analyzing the real work of the future RMSRP is therefore not possible. Traditional processes in training design like Systematic Approach to Training (SAT, Department of Energy, 1994) – the training design approach used at EDF

\(^1\) In RMSRP design process, the training design is considered as a sub-project. Training design began after the feasibility studies of RMSRP and the decision to install and deploy the RMSRP in all the French NPPs.
training unit (ETU) – or traditional techniques used to derive training content like Hierarchical Task Analysis (HTA, Annett & Duncan, 1967) rely on the analysis of an existing job or work activity. Thus, they don’t provide the theoretical and methodological framework to tackle the present issue.

In this context, this paper focuses on how to design training for a not yet existing activity like the one of future RMSRP operators. To address this issue we propose a new training design approach, called SITUAATING (SITUation and Activity bAsed TraNling desiGn), based on ergonomic work analysis in an activity oriented perspective (Boccara & Delgoulet, 2013). After a short review of the theoretical foundations of our approach, the limits of SAT are analyzed. Then, SITUAATING and how it has been implemented during the design of RMSRP operators’ training are presented. Finally, we conclude on the mandatory conditions to integrate permanently our training design approach into the training design process of ETU.

2 Design training from work-activity analysis: a short review of the theoretical foundations

Our approach belongs to the “French-speaking framework” which primarily focuses on the analysis of human activity in situations (Daniellou & Rabardel, 2005). In this approach, activity (and learning) is situated, i.e. it depends on the characteristics of situations, and the content and goals of the tasks given (Leplat, 1990; Hacker, 1985). The French ergonomics approach of work training is not new: from the first studies, researchers contributed to training design based on work analyses (see Teiger & Lacomblez, 2013 for a review). Today, learning processes at work and occupational-skills development are promoted by a constructive ergonomics approach (Falzon, 2015). Contributions to occupational training design are now numerous. They can be divided into five areas:

1) activity analysis in production-work situation to identify training goals and critical skills that have to be learned (Chatigny & Vézina, 1995), to design training tools adapted to trainee and trainer needs (Boccara et al., 2015), and to evaluate training curriculum (Delgoulet, 2001);

2) learning-activity analyses to identify trainees difficulties (Delgoulet & Marquié, 2002);

3) activity of occupational skills and knowledge transmission in work setting (Thebault et al., 2014) or in educative setting (Vidal-Gomel et al., 2012);

4) training of workers to do work-activity analyses in order to transform their mental representation of work situations and safety prevention (Teiger & Lacomblez, 2013). These studies have produced results on the efficacy and benefits of such training programs (Berthelette, 1995);

5) our contribution is a part of a fifth topic related to the project management of training design based on the “French-speaking framework” (Boccara & Delgoulet, 2013).

We consider human activity as an organized, coherent and meaningful whole that is constructed and performed according to situations. Then, the activity development in training depends on the characteristics of the training situations and their references to the real work situations. Therefore, the issue is not to identify skills and knowledge required, but to identify the situations, their characteristics and contents, and their dynamics that may support the skill-development process in line with the future work activity.

However, an exact reproduction of work situations in training is rarely a good support to the learning and skills development process. In fact, the main goal of real work situations is to produce, and not to train. This leads to making a “didactic transposition” from work situations in order to construct training situation as a support to occupational learning and skills development process (Chevalard, 1985). Based on Vygotski (1962/1986), Mayen (1999) calls this kind of situation, a “potential development situation”. To accomplish this, real work situations and work activity have to be analyzed with the aim of extracting and transposing (and sometimes deforming) their relevant characteristics.

Furthermore, we consider that trainers working conditions are learning conditions of trainees (Ouellet, 2013). Our training design approach aims to take into account the real working conditions of trainers from the first phase of the training design process. This brings us to the question of the favorable conditions towards designing, preparing, conducting and debriefing training situations for and with trainees in order to support occupational learning and skills development process. Thus, our approach aims to move beyond the classical approaches centered on either knowledge or trainees by considering trainer-trainees joint-activity.

3 Limits of Structured Approach to Training (SAT), the training design process at ETU

ETU adopted and adapted SAT about 20 years ago (IAEA, 1996). In this approach, workers are often
conceived as task executants accomplishing one or more prescribed goals. SAT is centered on identifying tasks and goals that trainees should learn, and the knowledge and skills required to perform them. It is then a knowledge centered approach. The main idea is to prepare trainees to execute the tasks that they will have to realize in their future job. From our point of view, this – rarely explicitly exposed – theoretical and methodological position has five major limits.

Firstly, in SAT, work activity is segmented: A) in different components (e.g. know, know-how to do, know-how-to-be), and B) in distinct tasks and goals seen as separated elements, independent from their meaning as a whole. Many researches in ergonomics have shown that work activity is integrated (Falzon, 2015). In other words, work activity is a meaningful whole whose components are interrelated. The risk associated with the segmentation of work activity is to lose its coherence. Then, the trainee will have toreassemble all the parts taught separately in a meaningful and operational whole. Thus, he could experience difficulties in transposing skills acquired during training into real work situations.

Secondly, SAT is based on the identification of competencies linked to the tasks to learn. This identification relies on the analysis of current and observable work. In the case of RMSRP, operators’ work activity doesn’t exist. Installed prototypes are not fully functional and not fully representative of the future RMSRP. Current RMSRP operators' work activity with the prototypes is very different from their future work activity. Thus, models and methods enabling the anticipation of the future work activity are needed.

Thirdly, SAT mainly aims at teaching rules and procedures enabling to deal with already regulated situations, i.e., situations where the problem and its solution are known. Yet, RMSRP aims also at dealing with complex situations where the problem has not yet arisen but can be anticipated. The strict application of rules and procedures do not provide the key to efficiently anticipate the reaching of tolerated limits. RMSRP operators will have to be able to detect and manage drifting situations on the basis of incomplete information evolving dynamically. In this case, the issue and the solution can’t be known beforehand. RMSRP operators will have to build the problem and its solution together according to the evolution of the situation.

Fourthly, SAT doesn’t provide a structured method to design training simulation scenarios. It doesn’t rely on theories providing sufficient work situations and work activity models needed to determine the relevant elements of complex work situations. Identifying these elements is a major step during the design of a training scenario, because the quality of a training situation is in relation with possible learning activity during training. In order to develop the competencies associated with the management of complex situations in a real work setting, the key elements structuring the work activity have to be reproduced in the training situation.

Finally, SAT tends to underestimate the importance of taking the trainers’ work into account during the design of training situations. If some organizational aspects are considered (e.g., staffing, materials needed to perform training), training situations are rarely taken as work situations for trainers. Then, the risk is A) to design training situations disconnected from the reality of trainers’ working conditions, and B) to consider the trainer only in its teaching role, neglecting, for example, the preparation needed, the complete assimilation of training content (e.g., simulation scenario), and the development of specific tools to conduct a training session.

4 SITUAATING: SITUation and Activity bAsed TraiNing desiGn

SITUAATING has been designed to tackle the limits identified in the actual training design approach used at ETU. The principles of SITUAATING are presented first, before exposing each phase in more details. These phases will be illustrated with the application of SITUAATING during the RMSRP operators’ training design.

4.1 Overview of SITUAATING approach

SITUAATING is divided into 3 phases (Figure 1). During work analyses, both the actual (or future) productive work (that trainees will have to learn) and the actual (or future) trainer’s work are analyzed. Then, the actual design and delivery of the training can occur and the training can be evaluated.

This approach is based on 4 strong principles. Firstly, it’s theoretically founded and driven by a theory of the functioning of humans in work situations, the Activity Theory. The actual or the future work activity are then central in our approach.

Secondly, there is no need to directly analyze or observe the work trainees have to learn, i.e. the future
activity. Analysis of work activity can be performed on a “reference” work activity, i.e. an activity that shares similar characteristics with the future activity. The characteristics of the future activity can be foreseen by analyzing the goals of the system design project, the expectations towards the new job, the characteristics of similar jobs, the characteristics of the work situations in which the system will be used, etc. During RMSRP operators’ training design, such analyses have been performed by the authors who are HFE experts.

Figure 1. Overview of the SITUAATING approach.

Thirdly, SITUAATING, is not strictly sequential, neither between phases, nor within the phases, nor within the sub-phases. If phase 3 can’t take place before phase 2 has ended, and if phase 2 can’t start before the first work analyses have been performed, the 3 phases don’t have to be performed sequentially. For example, after phase 3 has been performed, either phase 2 or phase 1 can be reconsidered.

Finally, our approach is participative: future trainees, future work activity experts, HFE experts, project managers, and technical system experts have to participate. Each of them has a specific point of view on the work or the future work, and carries a specific expertise needed during a training design project. Alternating between group work with all participants and individual work has to be programmed and organized. During RMSRP training design, this has been performed by HFE experts and the RMSRP project manager. Participation varies among the phases. During phase 1, trainer and future trainees share information on their specific area of expertise, i.e. their work. During phase 2.1, all participants work together to produce training content, but this content will be developed only by the trainers during phase 2.2. In the same way, only trainers and trainees will be involved in phase 2.3.

4.2 Phase 1: work analyses

The first phase of SITUAATING aims at identifying, analyzing and modelling A) the target work activity and the real work situations the trainees will have to be trained in, and B) the trainers/trainees activity. In the case of RMSRP training design, the target work activity is the future activity of the RMSRP operators. Modelling refers here to describing this activity, its components, its objects, the external and the internal factors that impact it, and its results and effects on the work situation.

In the present case, the activity model (phase 1.1) was constructed from: 1) multiple observations in real work situations with RMSRP prototypes, 2) interviews with future operators of this system and 3) strategic analysis of the project RMSRP goals (Fucks & Couix, 2014).

As training can’t deal with all the situations the trainee will have to cope with in real work settings, choosing the right work situations that will be used during training is an important step. Various techniques have been used during RMSRP training design. We conducted critical situations interviews (Flanagan, 1954). All the situations collected have then been prioritized according to the judgment of risk prevention experts and an empirical study where future RMSRP where asked to elicit how they would react to a specific situation using the RMSRP. The aim of this study was to determine the gap between the actual responses of

\[2\] This concept is inspired by the one of “reference” situation by Daniellou (2004).

\[3\] For example, future RMSRP operators have been compared to control room operators.
future RMSRP operators and the anticipated ones determined by risk prevention experts. The existing trainer-trainee work-activity was analyzed (phase 1.2) in order to identify actual conditions of work and learning in training. Trainer activity is: 1) a professional activity inserted into a work organization providing constraints and resources, 2) a didactical activity, they have to organize and support learning process of the trainees and, 3) a case of managing dynamic situations, namely the development of trainees’ skills (Vidal-Gomel et al., 2012). The trainer-trainee activity is considered as a joint activity rather than interactive activities (Boccara & Delgoulet, 2013) and, trainers working conditions are considered as trainees learning conditions (Ouellet, 2013). Thus, this step of SITUAATING aims to understand and characterize the actual training situation in order to evaluate possibilities and limits for the future training situation in the design process. During RMSRP operators’ training design, this analysis showed that designing training for a not yet existing work was a completely new perspective for trainers. This was then taken into account in the design process to anticipate, organize and support the mastering of the new training scenarios by trainers.

### 4.3 Phase 2: Building of the future training situation

The aim of phase 2 is to build the future training situation, i.e. the combination of the trainee and the trainer situation. This phase implies 3 major iterative steps: the design of the training scenario, the development of training material for trainers and trainees, and the delivery of the training. Each step contributes specifically to building the future training situation.

#### 4.3.1 Design of training scenarios

The aim of the design phase is to develop training scenarios. Several activities have to be performed: future work and situation characterization, identification of the work situation learning potential, feasibility analysis, training scenario writing, integration into the training program. These are detailed next.

**Future work and situation characterization.** The characterization of the future work aims at describing the relevant characteristics of the object of the activity to be trained in, i.e. what the worker is working on. For example, the object of the activity of future RMSRP operators is the work situation and work of maintenance workers. The output of this analysis is a list of characteristics of the objects of activity to be trained in.

Situation characterization aims at extracting elements that makes a work situation « emblematic » in order to determine the situation class it belongs to. More precisely, the aim is to describe all the characteristics of the work situations that are meaningful in the activity, e.g. elements useful for the decision making process of the workers.

A situation class is not a specific situation, e.g. the remote monitoring of specific maintenance work on a specific component of the plant on a specific day. A situation class refers to a set of specific situations that share similar and meaningful characteristics. To ease characterization of class situations during RMSRP training design, the work began with the characterization of a specific situation judged to be emblematic by risk prevention specialists. These situations were the starting point from which we determined progressively the characteristics of the situation class they belonged to.

Characterizing the situation class is important to offer some variability to the training scenarios. During RMSRP training design, variability has been brought about by unexpected events (from the trainee point of view), e.g. the irradiation goes too high during maintenance work monitored with the RMSRP. This way, it is possible to have various training scenario based on the same situation class.

**Identification of the work situation learning potential.** Once the work situation has been characterized, the learning potential of this situation has to be analyzed. The learning potential of a situation refers to what can be learned by the trainees when they have to cope with the situation. Nonetheless, as it depends on the coupling between the trainee and the training situation, learning is not guaranteed.

The learning potential of a situation can be divided into 3 “clusters”:

1. The situation cluster refers to the elements that are meaningful to efficiently perform the activity to learn. It’s a meaningful set of situation characteristics that will direct the trainee activity.
2. The technical system cluster refers to what can be learned in using the technical system when dealing with the situation.
3. The activity cluster refers to activity components that are crucial for the future activity and can be practiced when coping with the training situation.
These clusters can’t be dissociated. As they form a specific and meaningful combination, they have to be practiced together. They constitute the learning objectives associated with the work situation.

**Feasibility analysis.** The feasibility analysis aims at determining if all the physical, organizational and human components of the work situation relevant from the point of view of future activity are available in the training situation. More precisely, availability of these elements have to be checked: the trainee situation, i.e. the situation that the trainee will have to deal with, and the trainer situation, i.e. all the elements that makes the delivery of the training session possible for the trainers (maximum number of trainees, number of trainers needed, technical means needed, etc.).

If elements from the work situation are not available, feasibility analysis aims at determining the alternative elements that can be used to simulate the relevant characteristics of the real elements. For example, during some maintenance work, small radioactive pieces are pulled out from the reactor’s pool, which implies specific safety issues. Having a pool filled with water was not possible in the training setting. Nonetheless, from the RMSRP operators’ point of view, the relevant aspect is not the water in reactor’s pool. RMSRP operators will only need to know if the piece is in or out of the water. Thus, it was decided to only simulate the reactor pool’s waterline. Trainees will then be able to detect if the simulated radioactive pieces are in or out of the “water” and act accordingly.

**Training Scenario Writing.** When the training situation is considered feasible, then the training scenario writing (TSW) can take place. The TSW process aims to formalize the “training story”. This training story has to be consistent with the complexity of real work. Thus, we have to be careful during the design process to avoid either restrictive or generic scenarios for learning. In this way, scenarios must train to a situation class rather than specific situations. A scenario is structured by a series of parts. Each part refers to a sub-goal or a meaningful group of sub-goals. The phases of the work activity to be trained in are a support to design the parts of a scenario. A part is composed of series of events which dramatize potential learning goals for the trainees. Thus, one scenario integrates several possible learning routes for the trainee. They have to be anticipated and organized during the design process. This kind of scenario then offers multiple possibilities for the trainer to adapt training according to the actions of trainee during the training session.

**Integration of training scenarios into the training program.** When all training scenarios have been produced, they have to be integrated into the training program. It should also be organized to adopt a progressive learning by exposing the trainee to more and more complex scenarios. In the case of the RMSRP, six scenarios were produced to train the trainees to six critical situation classes. With the future RMSRP operators and the technical experts, scenarios were classified according to their difficulty level. Furthermore, the different possible learning routes inside each scenario were also classified according to their difficulty. These classifications could help trainers to organize the learning progressively when designing the training program.

### 4.3.2 Development of trainees and trainees materials

The development of trainees’ and trainees’ materials aims at designing pedagogical resources needed by the trainers to completely assimilate, to prepare, to set up, and to conduct the training and to lead the debriefing with the trainees. Various pedagogical resources need to be created according to these phases. Trainers have to write down everything required by another trainers who didn’t participate during the training design process.

For the preparation phase, trainers have to have a full understanding of what is at stake during each training scenario, i.e. what the trainer can do during training delivery and what the trainee should learn. For example, this pedagogical material can include a detailed description of training scenarios and the learning objectives associated. Some explanations of design decisions are needed to make the complete understanding of the scenario possible for a trainer that didn’t participate in the design process.

For the actual training delivery phase (setting up, briefing and conducting), trainers need 1) to know how to set up the initial state of the situation (list of material to install, map the situation with the location of physical elements, etc.), 2) to have elements to brief trainees on the situation they will have to deal with (contextual elements of the situation, etc.), and, 3) to have tools to support the actual training delivery that will help the trainer to monitor the trainee activity (e.g., the sequence of events and the various paths among

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1 When collaboration is an important part of the future activity, the trainers have to brief the people performing the interaction between the trainee and other working people. The performers can be other trainers, other trainees, or both.
them), and to adapt or change the training scenario in real time according to the trainee actions and progress (e.g., list of unexpected events and associated learning objectives, etc.).

For the debriefing at the end of the training scenario, trainers need to have pedagogical landmarks, i.e., critical points associated with learning objectives (e.g., actions the trainee needs to perform, likely errors, etc.). Nonetheless, the landmarks are just a part of the whole debriefing. During debriefing, more points could be brought up by the trainees. The debriefing is the perfect moment to re-building what actually happened during the training scenario with the trainee. One of the characteristics of the debriefing phase is that trainees are out of the dynamic of the actual situation. This way, they can reflect on their own activity during the scenario, the situation they faced, the decision they took, and the other ways they could have acted (Pastré, 1999).

### 4.3.3 Training delivery

When designing a new training program, and especially when a new training device has to be used, the training delivery has to be progressive. Firstly, we recommend to test the training with a simulation comprised of the real trainers, the real training setting, but not the real trainees. This step is crucial to identifying difficulties and correcting the training material (pedagogical settings and documents). Before going further, we strongly advise performing several iterative evaluative tests (phase 3) until all “bugs” have been identified and treated. During these tests, trainers will also master the training situation more and more and they can project themselves into their future work situation. This could support the appropriation process of the new training.

Secondly, a first training session with real trainers and real trainees has to take place. This training session is the ideal moment to perform a more thorough evaluation (phase 3). Then, finally, after results from the evaluation have been analyzed and taken into account, the training can go on. In this way, it is very important take a moment to reflect on the training before starting the real training.

### 4.4 Phase 3: Evaluation

The evaluation phase is performed in parallel with the training delivery. Both quantitative and qualitative methods have to be used. During the first test session, evaluation output will be used to improve the training material and setting. If a new training device is used, the evaluation phase is also very important to understand and analyze the changes brought to the trainers work.

During the first real training, evaluation can proceed on the whole training situation. The evaluation has to take the trainers and the trainees points of view as well as their interaction into account. After the first training session, the evaluation is part of a continuous improvement process.

### 5 Discussion

This paper presents the SITUAATING approach, built and applied during the RMSRP operators' training design. Although SITUAATING is still under development, the conditions to use this approach as the main process for designing new training programs can already be discussed.

SITUAATING is a proposition of a training design process oriented by a work activity framework. SITUAATING differs significantly from the design process (based on SAT) currently used at ETU. Two major differences make the adoption of SITUAATING a big challenge. Firstly, SAT is knowledge based, focusing on the knowledge (mainly all the tasks and goals of the job considered separately) the trainees will have to acquire during training. SITUAATING is work-activity and situation based, focusing on the integration of the multiple components of work-activity (e.g., all the tasks and goals of the job are considered as interdependent) to deal with the work situations. Moving from SAT to SITUAATING is then a major shift in theoretical position. Real work activity and situations have to be analyzed with the framework adopted in SITUAATING, i.e. the Activity Theory. Then, if trainers from ETU want to use SITUAATING without help from HFE experts, they have to be trained in its theoretical foundations and its methodological implications. Trainers need to have time and resources to get a comprehensive understanding of the approach, and, thus, their management has to be supportive and involved.

Secondly, SITUAATING is a participative design process. This approach is not “check-list” style. Various
people with specific knowledge and points of view have to be involved during the training design process. Then the design process has to be socially constructed, which implies specific skills. Resources allocated to the design process must also take the time needed for participation into account. Nonetheless, once mastered, SITUATING can be applied more quickly or less quickly according to the expertise of the analyst: the greater the experience, the quicker the analyses.

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