A MULTI-LEVEL ACTIVITY ANALYSIS FOR HOME HEALTHCARE ICT TOOL REDESIGN

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Abstract

When organizations want to innovate in their Information Systems, they often base the new ICT tools on already existing applications. However, each organization is different and has different needs towards the ICT use. The redesign of software requires a lot of resources (people, time, money), and is not always possible. Moreover the transformational link between the user task and the tool will lead to the organizational change, that has to be anticipated in order to promote the integration of the sociotechnical innovation.
In this study we therefore sketch the framework of an approach for the management of sociotechnical innovation; including (1) ICT redesign, (2) business process redesign, and (3) user support for the appropriation of change. We develop more particularly the approach of Activity-Artefact Cycle Analysis, based on Activity Theory and Task-Artefact Cycle. Our first results show how the detailed activity analysis can guide to the redesign of existing software. The work presented in this paper is part of a PhD research project in partnership with a home healthcare organization, whose objective is to introduce electronic healthcare record at patient's house.

Keywords: User centred design, Design methodology, Evaluation

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

In the fifth era of Information Systems (IS) evolution (Laudon and Laudon, 2013), we can observe Information and Communication Technologies (ICT) in various professional contexts. Their constant evolution is particularly noticeable in the last few years. We experience an explosion of new tools, devices and services, as for example cloud computing and applications for Smartphones and tablet PCs. Today different organizations have to learn how to make profit of these evolutions, and how to fully take advantage of new technologies as support for their business processes.

The choice of the approach to adopt is not a simple decision for organization's leaders. Design a new application? Buy an existing one, and maybe try to adapt it? The design from scratch is rarely used for Information System applications, as their complexity requires an important amount of resources for IT development. On the other hand, the implementation of existing software nearly always requires some adaptations, and leads to the signature of a development recipe.

Independently of the selected approach, the implementation of new IS tools in professional context is not only the matter of ICT design. It will involve the mutual transformation of the organization by the technology and of the ICT by the organization, in a two-way process (Berg, 2001). A prior definition of the model of the actual system is a prerequisite for the study of IS introduction (Blanc, 2005) and can guide the reflection in the context of different user needs (Scandurra et al., 2008).

The key aim of our research is to propose a framework for the accompaniment of organizational innovation linked with the implementation of new technological tools (ICT) within the organizational Information System. More specifically, through the concept of usage we aim to study the accompaniment of the bi-directional transformation of the organization by the new IS tool and of the IS by the organization within the constraints of real-world business settings. Our approach to the analysis of the link between the organization and the IS tools is inspired from the Task-Artefact Cycle (Carroll and Rosson, 1992; Carroll, 2014) and Activity Theory and Analysis (Engeström, 2000; Kaptelinin and Nardi, 2006; Bardram and Doryab, 2011).

The objective of this paper is to present first part of our approach, concerning one direction of the transformation, where an organization proceeds to the ICT choice, evaluation and adaptation through redesign. The results presented come from experimentations realized within a home healthcare organization (HHO), willing to introduce the electronic healthcare record (EHR).

We begin with a brief description of our home healthcare case study (Section 2). After the presentation of selected theoretical background (Section 3), we introduce the Activity-Artefact Cycle Analysis (Section 4). Next we illustrate the application of our approach to ICT redesign (Section 5). Finally, we summarize our findings and describe future work (Section 6).

2 HOME HEALTHCARE CASE STUDY

Home healthcare structures in France exist for about 50 years. They achieve similar activities as public or private clinical practice, with the main difference that the patient's room is situated in patient's household. This direct correspondence impacts home healthcare in many significant ways. Firstly, and most importantly, HHOs and hospitals have the same objective: a quality patient healthcare. Thus they share the most important IS tool used within the medical practice: the patient record (PR).

As part of the Health Information System (HIS), the patient record fulfils two main functions: storage of data and coordination of activities and events. Both of these functions are primordial to medical work and are independent of the form of the record: paper-based or electronic-based (Berg and Toussaint, 2003). If today in hospitals the PRs are electronic, it is not yet the case for all home healthcare organizations. As within the home healthcare practice different patients are situated outside the office walls, it proves to be more difficult to implement ICT directly at the point of care (Bricon-Souf et al., 2005). Therefore, HHOs often have the PR in two forms. The first one is electronic, is part of the business-specific software at the office, and contains mostly administrative and selected medical data for healthcare management. The second one is a paper notebook or binder, placed at patient's house, containing all detailed data about the healthcare provided.

Our research project is carried out in partnership with a HHO willing to replace the paper healthcare record (PHR), in form of a binder, by and ICT tool with electronic healthcare record (EHR) software. The main objectives of the project are to (1) facilitate and secure information transmission through distant direct access to the EHR by professionals outside the patient's house, (2) and to secure the

medication circuit by introducing a unique support for medication management. The home healthcare organization has two usual options: design or buy the EHR software (Borgiel et al., 2013).
The project is linked with different challenges, and the most important issue seems to be the influence of the change of support (from paper to electronic) on the work of different actors within the organization. How will the distant access to detailed healthcare data impact the coordination by care managers at the office? How will the EHR be used by different professional actors that take care of patient at his home? To answer these questions, one would need to have an understanding of the existing activity with the PHR, and an understanding of the EHR software to implement.

3 SELECTED THEORETICAL BACKGROUND

3.1 The usage of tools

Tools, both material and cognitive, are extensions of human being in his activity. For example, Information System tools enable people to collect, to create, and to distribute useful data, typically in organizational settings (Valacich and Schneider, 2014). To accompany the organizational innovation with new ICT tools we propose to build on the concept of usage of work tools. We define usage after (Proulx, 2005) as the use of a material or symbolic object for a particular purpose; or as a series of practices that became normal within a given culture by their seniority or frequency. The concept of usage captures the relations between the object, the individuals, the routines and the professional practice within a community. It develops over time within the constraints of the real activity, imposed by the activity and different supports. In order to understand the usage of a tool, we need to analyse the constraints of tasks and the possibilities of the tools within the context of work.

3.2 Task-Artefact Cycle

As states Coeira (2004) *'technical systems have social consequences, and social systems have technical consequences'*. The transformative link between technology and organization within the natural evolution of work and its tool is the direct parallel circular link between the task and its artefact (Carroll and Rosson, 1992; Carroll, 2014). The cyclical relationship is represented in Figure 1.

Figure 1. Task-artefact cycle (Carroll and Rosson, 1992; Carroll, 2014)

- A given task is the source for the definition of requirements for the design of an artefact, which can be understood here as a technological system combining hardware and software sub-systems;
- The resulting artefact creates new possibilities and/or new constraints for the task;
- As a consequence, the original task is not any more accomplished in the same way; the artefact can be further redesigned in order to better satisfy the new requirements, or in order to reduce the way the task is modified by the use of the artefact.

The most important consequence of this iterative process is that, within the mutual adaptation between the two elements, both task and activity will never reach an optimum state. We argue that it can be however captured and "frozen", within the project of the ICT (artefact) change. The analysis of the role (usage) of the existing artefact is the basis for the evaluation of the new one.

3.3 Activity Theory and Activity Analysis

Activity Theory (AT) is a descriptive framework to capture the complexity of sociotechnical systems (Engeström, 2000; Bardram and Bossen, 2005; Kaptelinin and Nardi, 2006).
The activity system is composed of different *subjects*, within a specific *community,* whose actions are realized on *objects,* in order to achieve a specific *outcome*. People (subjects) interact with the world and achieve their outcomes not directly, but mediated by diverse elements developed for their needs

over the time. They use different *artefacts*, physical and mental tools, in order to manipulate the objects. They act within a community that has its *rules and traditions*, and the collaboration is achieved by definition of *roles and the division of labor* between persons and/or professions. Finally, human activity is executed at three hierarchical levels (Table 1).

Table 1. Dynamic structure of activity (Kaptelinin and Nardi, 2006)

LEVEL	DIRECTING FACTOR	SUBJECT
Activity	Object / motive	Collective
Action	Goal	Individual or group
Operation	Conditions	Non-conscious

Activity Analysis (AA) is a method for leading and analysing field studies based on Activity Theory principles. *'The purpose of the Activity Analysis method is to provide a detailed account and understanding of human activity as enacted collaboratively within the resources and constrains of a real-world setting'* (Bardram and Doryab, 2011). The application of the AA method is usually done in two steps: (1) detailed study of work activity through classic qualitative methods (participative observation and recording, interviews, artefact studies); (2) analysis of selected activity patterns based on concepts from Activity Theory. The added value of AA is the ability to describe the studied activity on different levels of granularity (activity-action-operation), with the reference to actors, artefacts, and the context of use.

4 PRESENTATION OF OUR APPROACH

4.1 Sketch of the Activity-Artefact Cycle Analysis

The key aim of our research work is to **accompany the bi-directional transformation of an organisational system in a project of new IS tool implementation.**

We propose to approach this transformation by the analysis of the direct link between the tool and the organizational processes supported by the tool, in terms of requirements, possibilities and limits. The results from the analysis are next used for decision making about: (1) the redesign of the ICT; (2) the reengineering of business processes (BP), and (3) the user accompaniment for the appropriation of the change brought by the project.

The **Task-Artefact Cycle** model motivates the bi-directional character of the analysis. Every change in the artefact is studied in the context of supported tasks, and every need of change in the task should find a match in the evolution in the artefact. The **Activity Theory and Analysis** motivate the multi-level study of the link between the artefact and the activity, in order to capture the multi-level role played by artefacts in organizational performance.

Thus, in order to avoid any confusion about the magnitude of our approach, we propose to call it the **Activity-Artefact Cycle Analysis** (Figure 2).

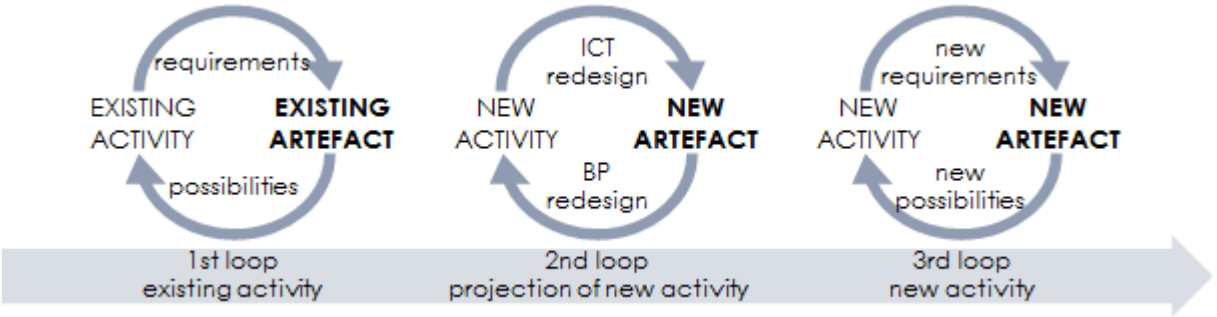

Figure 2. The illustration of Activity-Artefact Cycle Analysis

The analysis is leaded through the iterative comparison of the Activity-Artefact Cycle (AAC) with the **existing artefact** (first loop) and with the **new artefact** (Figure 2) and **new BP** in the next loops. The description of the AAC with the new artefact is firstly a projection (second loop), when done before implementation, and next becomes the description of the real activity after the transition (third loop). Thus the AACA can be used throughout a new ICT tool implementation project.

4.2 Steps for ICT redesign

Considering the project of new IS tool implementation, the first step is to analyse the existing work: study business processes and supporting them tools at different organizational levels. This leads to a detailed definition of shortages of the existing artefact, and the improvements needed by the organisation and its employees. The diagnosis has also to take into account the constraints of the organization. Next, specifications for the technological tool (application and device) can be defined in order to identify available systems and related editor companies. The ICT tools are then evaluated, and their redesign is studied with the editor if needed. Figure 3 illustrates the different steps for the phases of ICT redesign.

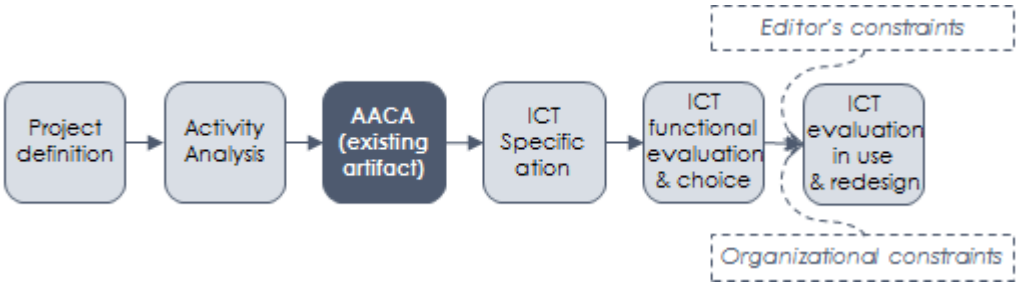

Figure 3. Steps for the first phase and the second phase of our approach

Every step corresponds to a specific objective in order to enable the achievement of subsequent steps. It is important to mention that even if the objectives presented in the Table 2 below are quite general, their execution can be done on the lowest level of granularity (operations). The depth of analysis concerning the activity-action-operations hierarchy is adapted to the organizational context.

Table 2. Summary of objectives of different steps

PHASE	STEP	OBJECTIVE
Phase 1	1.1 Project definition	• *define the tool and the activity to analyse*
	1.2 Activity analysis	• *analyse the current use of the tool in the organization, its usage and role in the IS*
	1.3 Activity-Artefact Cycle Analysis (existing artefact)	• *identify how the existing tool supports and limits the current activity* • *identify the needs that will have to be satisfied by the new tool, and how they relate to the global activity*
Phase 2	2.1 ICT specification	• *specify new tool requirements*
	2.2 ICT functional evaluation and choice	• *evaluate tool candidates and select one*
	2.3 ICT evaluation in use and redesign	• *evaluate the selected tool (up to the operation level), and redesign it if necessary*

The validation of our approach is done successively through its application within our case study project. In this paper we present the results for the steps concerning the artefact-oriented transformation. In our case, it concerns directly the evaluation of the new ICT tool and its redesign based on the description of the first loop of Activity-Artefact Cycle.

5 HOME HEALTHCARE STUDY

In this section we describe how the application of the initial steps of our approach leads to the redesign of an ICT tool. The techniques used are those widely used within existing user-centred, human-centred design approaches (International Standard Organization, 2010; Hartson and Pyla, 2012; Preece et al., 2015). We illustrate our approach through the example of medication circuit management within the HHO studied, the medication prescription (Table 3). With reference to AT framework, and for the needs of our study, we position the medication circuit management on activity level, and the medication prescription on the level of actions.

Table 3. Example of home healthcare activity of medication circuit management

ACTIVITY LEVEL	ACTION LEVEL	OPERATION LEVEL *(for the action of prescription)*
a. medication circuit management	a.1 prescription a.2 delivery a.4 administration a.5 monitoring and evaluation	a.1.1 indication of the prescriber a.1.2 indication of the products a.1.3 indication of treatment duration a.1.4 indication of treatment dose a.1.5 indication of route of administration

5.1 Activity analysis

Data collection about the medication prescription is done as part of the data collection about the global home healthcare activity and the usage of the PHR. The latter one is done through participative observation of the care givers uses, through interviews, and through artefact study.
The PHR is analysed through document analysis (blank and already used), surveys, and direct observation. One of the authors follows 5 nurses and 5 nursing aids on half-day rounds, each concerning at least 4 different households. As for privacy issues it is impossible to directly observe the visits of family doctors, the semi-directed interviews are conducted with them concerning medication circuit. Different HHO employees are interviewed to complete the observations and the PHR analysis, including nurses, nursing aids and coordinating doctors.

5.2 Activity-Artefact Cycle Analysis for existing artefact

Medication prescription is essential in healthcare services provision. It enables patients getting pharmaceuticals and other medical products necessary for their care. The medical process corresponding to all actions from treatment prescription, acquisition, through its administration to the monitoring of effects is called the medication circuit. We investigate here the first action, executed by the family doctor, the medication prescription. We distinguish between the initial prescription and the medication prescription over time (the management of changes in patient's treatment).
In the HHO studied, the principal tool supporting the medication prescription (and medication circuit management) is a paper document, situated in the PHR. It is a double A4 sheet, where the left side is reserved for the prescription written by the doctor, and the right for the traceability of drug preparation and/or administration by nurses. In this way, nurses can trace every operation in front of the corresponding product. This paper document satisfies a set of requirements, but somehow limits the medication circuit management in the home healthcare organisation (Table 4).

Table 4. Results from the Activity-Artefact Cycle Analysis (existing artefact, action a.1)

activity requirements on existing artefact	• *the medication prescription is realized at patient' house by the family doctor, who is the principal medication prescriber* • *if there exist other prescribers (i.e. hospital doctor), it is the family doctor who is responsible for the control of the medication list* • *the prescription has to be composed of a specific list of elements in order to assure a quality management of medication circuit* • *a unique support has to be used for all actions of medication circuit* • *the same medication prescription support has to be used for all home healthcare patients, and thus by all family doctors* • *the maximal duration of every prescription is 28 days*
existing artefact possibilities for activity	• *individual sheets of the support are used for different types of medication (anticipated medication, dressings, ...)* • *the unique support is used for the traceability of preparation and administration for prescriptions made on other types of supports*
existing artefact limits for activity	• *each medication renewal requires the doctor to recopy the complete list of the treatment on a new sheet* • *the complete treatment list is accessible only at patient's house* • *the handwritten medication prescription lacks legibility, and its content is often insufficient for quality medication management*

The definition of possibilities and limits of the existing artefact for the home healthcare activity is directly related to the usage of the paper support by different actors.

5.3 ICT specification, functional evaluation, and choice

The change of an artefact usually aims at overcoming the limits of the existing artefact, bringing new possibilities with the new one, while respecting the global activity requirements. Better management of the medication circuit is one of the main objectives of the introduction of EHR in the home healthcare organization studied. Thus, the global specification for the ICT to be implemented is to offer the functionality of medication circuit management in the home healthcare context (Table 5).

Table 5. General specifications for the new ICT tool concerning the action a.1

general ICT specifications	• *be used at patient's house* • *provide functionalities for the management of medication circuit* • *provide access to the medication list and to selected medication management actions outside the patient's house*

After the initial benchmark of the market, it appears that there is only one ICT tool available that can cover the functions of patient healthcare record and medication circuit management. It is chosen by the home healthcare organization leaders. The software editor is willing to create a partnership with the HHO in order to make it evolve and to adapt it to specific business needs. A detailed evaluation of the ICT use is initiated.

5.4 ICT evaluation in use and redesign

5.4.1 Two steps of ICT evaluation

In order to define very specific redesign requirements, we conduct a detailed evaluation of the ICT software, based on the previous AAC analysis. Concerning the medication prescription, the evaluation is done in two steps.

The first step is the evaluation through the execution of a basic scenario of prescription creation. The scenario is created based on the list of elements that should be present on every medication prescription (defined by law), and on the examples of medication prescriptions issued from existing patients. The objective of this first step is to evaluate the adaptation of the software to the global constraints concerning the prescription creation in the medical context.

The second step is the field observation of doctors prescribing with the proposed ICT tool during the pilot phase of the EHR use. Indeed, in order to test the EHR use, the home healthcare organization decides to implement EHR for six different home healthcare patients (before any development of the EHR). The observations are realized directly at doctor's offices and the only instruction is to copy the actual list of patient's treatment into the EHR software. Four out of six doctors give their agreement for the recording of doctor-observer verbal exchanges during the meeting.

5.4.2 Results of ICT evaluation

The first step of ICT evaluation (scenario) confirms that the software allows for entry of all data forming a medication prescription according to French regulation policies. Furthermore, it is identified that the software imposes the medication prescription by type of product (non-injectable, injectable, dressing, nutritional supplement). Finally, it allows to define the list of new artefact possibilities for the activity (more precisely, for the action of medication prescription; Table 6).

Table 6. Possibilities and potential limits of the new ICT artefact for action a.1

new artefact possibilities for activity	• *medication prescription with direct access to medication database* • *medication list accessible outside the patient's house* • *medication prescription, modification, renewal and stoppage possible outside the patient's house* • *automatic management of the current medication list* • *automatic transmission of medication prescription to the pharmacy*

new artefact potential limits for activity	• *prescription entry with the stylus is not legible enough for the quality management of medication circuit* • *product name entry through access to medication database (on-screen keyboard) enables to prescribe only products listed in the database* • *automatic medication management rule is not adapted for all medication types, for example for wound dressings, where nurses do not trace the "administration" of the wound dressing products*

The second step of ICT evaluation (observation of doctor's recopying a list of medication) is particularly adapted to the identification of potential limits of the software for medication prescription. If the new artefact possibilities for activity are part of the IS change objectives, the new artefact potential limits form naturally a list of elements that could be redesigned in order to adapt the ICT to the home healthcare organization studied.

5.4.3 ICT Redesign

Based on evaluation results, the decision of ICT redesign is made by the home healthcare organization professionals, and the list of detailed redesign specifications is prepared (Table 7).

Table 7. Redesign specifications for potential limits of the new ICT artefact for action a.1

POTENTIAL LIMIT	REDESIGN SPECIFICATION
prescription entry with stylus	• *prescription entry through on-screen keyboard* • *integration of specific text-entry buttons for long text entry*
product name entry with on-screen keyboard	• *possibility to write a product name (free text) on the on-screen keyboard if the desired product is not in the medication database*
prescription management over time based on the traceability of medication administration	• *prescription management over time based on the type of treatment in the healthcare activity (in-depth, occasional, or anticipated)* • *distinction between the date of medication prescription and the beginning date of medication administration* • *presence of alerts representing the state of every prescription (on-going, to stop in x days, to expire in x days, expired)*

The redesign requirements concern more particularly the prescription with an on-screen keyboard and the change of automatic prescription management rules. After the editor's initial agreement to develop these new functionalities, a detailed mock-up of new interface is created with participation of home healthcare coordinating doctors. The redesign mock-up is made not only on the basis of existing support use, but also in relation with the design of software usually used by doctors to prescribe in their cabinet, within the constraints of the EHR software. A demonstration version of the new interface on a tablet PC is created based on the prescription scenario. It is next presented to selected family doctors for feedback. Finally, the mock-up is send to the software editor for development (Figure 5).

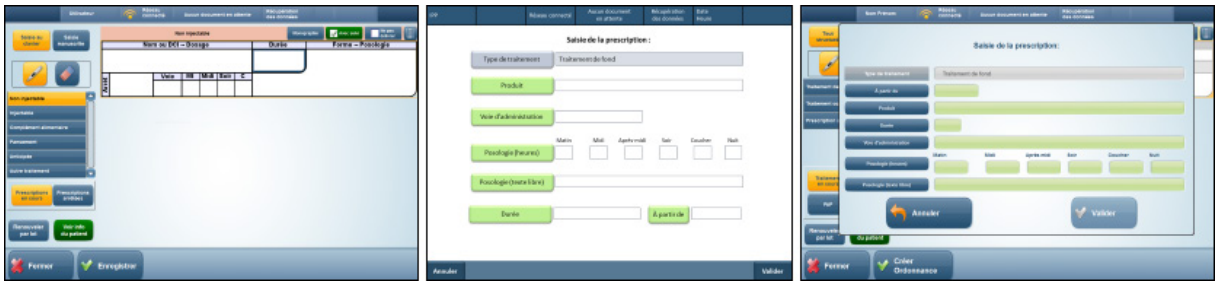

Figure 5. Illustration of the evolution of studied interface from the initial version (on the left), through the mock-up (in the middle), to the final version (on the right)

It must be noted here that the final redesign of the software depends not only on the constraints imposed by the home healthcare organisation, but also on the constraints imposed by the software editor. Indeed, the redesign specifications are implemented within the already existing software architecture and interaction.

5.5 Results and discussion

The key aim of our research is to propose a framework for the accompaniment of innovation linked with the implementation of new ICT tools within the organizational Information System. To meet this objective, **we propose to analyse the bi-directional link between the IS tools (both the existing one and the new one) and the organizational activity in terms of requirements, possibilities and limits**. We call this approach to analysis the Activity-Artefact Cycle Analysis (AACA), and we present its application within two first phases of an IS implementation project: (1) analysis of the existing activity with the existing artefact, and (2) choice, evaluation and redesign of the new ICT tool. The example of medication prescription from the HHO case study shows how the AACA can guide the specification, evaluation and redesign of the EHR. **Through the iterative analysis of the Activity-Artefact Cycle, it provides a detailed description of different medication prescription requirements (independent of the support), and of possibilities and limits for the activity brought by the PHR and the EHR.** The results from one step form the input for next steps. In this way, we can provide the description of the tool-oriented transformation during the implementation, and provide adequate **support for decision-making about the need of ICT redesign**.

The application of different steps of AAC analysis proves its role in the definition of redesign specifications related to: what functions are needed for ICT users, how these functions are to be proposed, how they are to be managed, what rules have to be applied for the data management generated by these functions, and also how the data has to be managed by users (access, visualization, creation, modification, evaluation, validation…).

Even if this approach seems today quite promising, it has not been fully tested yet. The work presented in this paper covers only two phases of an ICT implementation project, where the objective is to manage the sociotechnical innovation (Table 8). The results from the Phase 2 show how to proceed for the ICT redesign, according to organizational and editor's constraints. Within our case study we also identify some ICT specifications that cannot be satisfied by the selected ICT tool, given the different constraints. When the technological redesign is not possible, how to accompany the organization and different actors in order to overcome the pre-assumed limits of the new tool?

Table 8. Proposition of phases for the management of sociotechnical innovation

Phase 1	Analysis of the existing activity
Phase 2	Choice, evaluation, redesign of ICT tool
Phase 3	Definition and redesign of business processes
Phase 4	User support for change appropriation

The implementation of a new ICT is supposed to bring new possibilities for the organization; our approach must be then able to accompany the evolution of business processes supported by the new tool. This matches the phase of the analysis of transformation of the organization by the new tool (Phase 3). The challenge here lies in the definition of new business processes without a direct parallel in existing home healthcare activity.

Finally, given the analysis of evolution both on artefact and activity side, adequate user support activities have to be implemented (Phase 4). The accompaniment will have to engage both the accompaniment to the use of the new tool and the accompaniment of the evolution of professional practices and organizational change. We argue that this step is essential for the appropriation of the change brought by the project.

6 CONCLUSION

The key aim of our research is to propose a framework for the accompaniment of organizational innovation linked with the implementation of new technological tools (ICT) within the Information System. More specifically, through the concept of usage we aim to study the accompaniment of the bi-directional transformation of the organization by the new IS tool and of the IS by the organization, within the constraints of real-world business settings. In this paper we describe our approach for the accompaniment of the co-evolution between technologies and organizations in terms of requirements, possibilities and limits, the Activity-Artefact Cycle Analysis (AACA). The objective is to provide an adequate support for the decision making about the redesign of ICT tools, the reengineering of BP, and the resources needed for a better appropriation of sociotechnical change by the organization and its

actors. First results of the application of AACA within a project of introduction of electronic healthcare record in a HHO are encouraging. Through the example of medication prescription we show how an EHR software can be adapted, according to different expressed and less direct needs.
Our future work consists in the application of the AACA within the Phases 3 and 4, in order to accompany the transformation of the organization by the new tool, an in order to accompany different actors of the home healthcare organization in the evolution of work tools and practices.
We believe that the AACA is a promising tool to guide the different decisions about the implementation of new technological tools in organizations. However it would be interesting to develop the bi-directional Activity-Artefact link by including other dimensions of change. Indeed, it is proven that the change of an IS impacts organization not only on the level of the tool (artefact) or processes, but can also impact its culture or politics (Cameron and Green, 2012).

ACKNOWLEDGMENTS

The authors thank the study participants, the home healthcare organization *Santé Service Bayonne et Région*, and the software editor company *MHComm,* for their contribution to this research project.

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