THEDRE: A Traceable Process for High Quality in Human Centred Computer Science Research

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Abstract

Computer scientists in information system encounter difficulties in leading research when they must consider human aspects, especially to evaluate these aspects. To achieve high quality research, they need to be guided in their process from their research question to their contributions. This article addresses the question of a traceable process to lead research in human-centred computer science (RHCCS). It proposes, THEDRE, a method to lead RHCCS with 1) an epistemological posture based in "constructivism pragmatic" and 2) an adaptation of quality management concepts "Deming's wheel and indicators to follow a research process". Our proposal has been designed from our participation in 29 works in human-centred computer science, and more particularly with 8 PHD students in information system. Also, THEDRE has been experimented during 2 workshops with PhD students and researchers.

Keywords: Traceability, process, Deming's wheel, indicators, quality, epistemological paradigm, design science.

1 Introduction

Research in human centred computer science (RHCCS) considers people and their computer support, for their work (in the information system domain), their learning environment (in the learning domain) or their interaction with the machines (in human-computer interaction). It needs to include humans in the research process to build and evaluate scientific knowledge. But addressing human question can be difficult for researchers, especially for PhD students, who are not trained in social science. For producing high quality contribution, they need to be guided in their research process from a research question to contributions particularly during experiments with users for producing high quality data. This guidance is a way to achieve traceability during research activities. It allows researchers to keep track of their activities, of the research documents created (experimental protocols, analysis, etc) and of the data produced. These elements are crucial to ensure the quality of scientific results [1].

This article proposes a traceable process leading research in the RHCCS context. It aims at helping in producing high quality contributions thanks to guidance in leading research, especially in conducing experiments and in producing result data. To address these organizational needs of research in the context of the computer science and more precisely in the field of information systems (IS), Hevner [2] proposes an approach to lead research: the Design Science (DS). Several authors [3], [4], [5], [6] improved this method, but none of them addresses the problem of traceability. In this paper, we propose a method named THEDRE to guide and keep tracks of research in RHCCS. We explore the integration of continuous quality improvement concepts (i.e. Deming's wheel and indicators), in the research process.

The rest of this paper is organized as follows. First, we explain concepts related to RHCCS. Then, in section 3, we review the literature. In section 4, we present our concepts and work about Deming's wheel and quality indicators to add traceability in research process. We explain how our proposal was designed and evaluated and we conclude with perspectives.

2 Concepts for RHCSS

A research approach requires to rely on a epistemological posture [7] [8] because it defines how scientific knowledge can be built. So first, we need to define what is a scientific knowledge in RHCCS.

RHCCS belongs to sciences of artificial [9] because it is a research that requires the creation of artificial tools such as prototypes, to elaborate a scientific knowledge (e.g. a conceptual model). But it also requires being human-centred as the artificial tools are elaborated for human. The presence of users is the first RHCCS characteristic. The second characteristic is its dual goals: on the one hand, it aims at creating scientific knowledge; on the other hand, it designs tools for human activities such as a domain specific language or a user interface. These two kinds of production are closely interlaced and interrelated. For instance, a domain specific language is a scientific knowledge, which is concretized by some models or some prototypes implementing it. So we consider that the production of RHCCS is an instrument, which includes some scientific knowledge and activable tools. The scientific knowledge represents the research production. It is built from past knowledge. The proposal of new knowledge brings an added value to the past scientific knowledge. This added value is measured during experiments. The definition of scientific knowledge will be refined in section 4 which will define the way the scientific knowledge is built and evaluated, i.e. the epistemological posture. Sciences of artificial creates activable tools. An activable tool represents a usable form of the scientific knowledge. It is the medium between users and the scientific knowledge. It can be dynamic, if it is somehow automatic, or static if it does not rely on a technical tool. Concretely, during the creation of a domain specific language, some translation rules can be created to generate code. First they will be elaborated on paper (static) with domain experts before becoming dynamic by being embedded in a prototype. So, activable tools are designed, improved and assessed during experiments. An activable tool can be composed of several parts, named activable components, which form a consistent whole. But these parts can be isolated from one another to be built and evaluated by users. They can be considered as activable tools in the sense that users can use them. For instance the prototype supporting a domain specific language and some transformations rules into code can be composed of 2 components: one component for creating a model instantiating the domain specific language and one component for automating the tranformation rules. Each of them can be considered as an activable component that can be designed and evaluated separately. The activable components which compose an activable tool, as well as their development state must be identified, then built and evaluated during experiments.

These concepts of instrument, scientific knowledge, activable tools and components are the artefacts that will be manipulated during RCHCCS processes. So they need to be considered while designing such a process. We will use them to define our contribution and especially, to identify which of these concepts are built and evaluated all over the research process. First they will be used in the study of related work to define analysis criteria.

3 Related work

Promoting high quality research and particularly ensuring the traceability in a RHCCS process means that: 1) the description of the process must be precise enough to be traceable; in information systems design traceability is usually managed thanks to models and links between them, so for RHCCS, we expect the process to be described by a model, 2) especially the experimental aspects, which are related to the humans, must be detailed to be traceable and to promote a collect of high data quality, 3) some tools must be used to keep track of the process and to follow the quality of research data (working documents, experimental data, etc), 4) the process must make a clear distinction between scientific knowledge and activable tools so as to allow RHCCS researchers in identifying their contributions and 5) the value and the validity of the scientific knowledge must be defined in the epistemological posture to help researchers in evaluating their contributions. These five elements constitute our criteria to analyse related work.

Three main approaches have been used in the RHCCS domain: 1) in Technologies for Enhanced Learning (TEL) Design Based Research (DBR) [10] are often used 2) Action Design Research (ADR) [11] is an oldest method which is used in different scientific domain where human are implied during research process and 3) Design Science (DS) [12] [13]proposed by Hevner to lead research in Information System. But, none of them use tools from quality management and the experimental process is not described. However, DS [12] is a good candidate to answer to our criteria. It is composed of three cycles: 1) the relevance cycle to link research with its environment, 2) the rigor cycle which relates the research activities with existing knowledge in research, experiences and expertise and 3) the third cycle, that deals with the building of an artefact, its evaluation and its improvement. These three cycles are a first manner to guide research by providing a global process (criterion n°1). Moreover, some authors propose enhancements of DS with an operational process, an anchoring in a epistemological paradigm, a distinction between knowledge and tools and a modification of cycle of pertinence.

Enhancement with an operational process: according to K.Peffers et al [3], DS is not adopted in the information system community because it only propose a mental model and does not propose a real process to follow. To avoid this drawback, they present a six steps process: “identification of problem, goals of solution, design and development, demonstration, evaluation and communication”. This proposal is interesting because it offers a process detailed enough to follow the DS approach, making it more operational (criterion n°1). However the experimental process is not explicit, so the second criterion is not validated.

Enhancement with an epistemological posture: at its origins, the DS is not anchored in an epistemological posture. K. Peffers [3] proposes the interpretativist posture which is not adapted to RHCCS because the data produced to build scientific knowledge are narrations. This is too limited for RHCCS, which also requires users tests. H. Pirrkalainen [4] identifies that this problem is partly resolved, as A.R.Hevner [13] brings DS into the constructivism posture by putting 12 *theses* to define this posture. For instance, *these n°2* is “ *Prescriptive research is an essential part of IS as an applied or practical Discipline”[13](chapter 5)*. In an epistemological framework, it is necessary to establish hypotheses ontological and epistemological hypothesis, goals, value and validity of research [14]. In the 12 theses of DS there is not distinction neither between the ontological and epistemological aspects, nor between goal, value and validity. So criterion n°5 is not met.

Enhancement of the distinction between knowledge and tools: The improvement proposed by S. Gregor et al [5] concerns the distinction between two kinds of knowledge: 1) the descriptive knowledge (the “what”) which is knowledge related to the natural phenomena and the laws related to these phenomena; 2) the prescriptive knowledge (the “how”) which explains how artefacts are built from knowledge foundation. This proposal is interesting because it makes the distinction between knowledge from the field (the “what”) and the modelled ones (the “how”). The authors also show the artefact decomposition. DS is the only approach that proposes this segmentation (criterion n°4).

Enhancement of pertinence cycle: A. Dreschsler et al [15] review DS by presenting the work from K.Conboy et al [6] which mix agile method and those from H.Pirrkalainen [4]. Following these works, A. Dreschsler et al [15] propose to improve their model by dividing the relevance cycle into two parts (1-immediate application context and 2-socio-technical system context). This proposal shows the importance to confront the artefact supporting the scientific knowledge with reality and to make experiments. But the experimental process is not explicit (criterion n°2).

DS and its extensions match well to some of our criteria (Table 1). It provides both an epistemological paradigm to identify how knowledge is created, a process for managing research and a distinction between scientific knowledge and artefacts [13]. So considering criteria n°1 and n°2, DS and its extensions propose a global process to lead research, but it does not give details about the experimental process. It does not provide guides to keep track of research activities and to guarantee high quality data (criterion n°3). For the 4th criterion, DS makes a first distinction between knowledge and artefacts, but this point is not precise enough. Lastly DS seems to be related to the constructivism posture, however it does not mention any criteria about value or validity (criterion n°5). Also, in [15] R.Wieringa and al indicate the necessity of a process and of an epistemological posture but they offer neither criteria of value and validity, nor quality management tools. To address these shortcomings, we propose a method to lead RHCSS, which is built upon an epistemological posture, criteria of research value and validity, and a process to trace these criteria.

	DBR [9]	ADR [10]	DS[11]	DS extension [2]	DS extension [4][12]
1) detailed process	No	Partially	Partially	Yes in 6 steps	Yes
2) detailed experimental process	No	No	No	No	No
3) keep trace of process	No	No	No guide	No guide	No guide
4) split knowledge & activable tool	No	No	no division of activable tool	No	in two knowledge 'how' and 'what'
5) value,validity & quality of data	No	No	No	No	No

Table 1: Summarize on the criterion used to compare the methods of design research

4 Pragmatic Constructivism for THEDRE

We first of all wish to refine and structure the epistemological posture. In [14] J.M Avenier presents and compares four epistemological postures: “Post-Positivism”, “Interprétativism”, , “Critical realism”, “Pragmatic constructivism”. We chose to situate THEDRE in « pragmatic constructivism» because it takes into account human in his context and it is a systemic approach. Furthermore, value and validity criteria of scientific knowledge are precisely described. We first describe our hypotheses for our proposal to understand how “real word” is used to build scientific knowledge. In the second part, we present the validity and value criteria for our research method, THEDRE. These two elements help us in defining process monitoring indicators.

4.1 Hypothesis and traceability

We make five assumptions to define the epistemological posture of our proposal. Four of them are directly related to the process traceability.

Hypothesis 1: humans have some representations of reality. These representations are linked to the context where humans evolve. They can change over time or accordingly to personal events such as a change of profession, or technological evolutions or societal facts (e.g. the events of September 11th 2001). So it is important to date a representation of reality. This hypothesis brings the necessity to keep track of the research context.

Hypothesis 2: a human being will express his/her knowledge about the world he/she knows with some symbolic constructions named representations. This hypothesis brings the necessity to keep all data produced by human during experiments.

Hypothesis 3: scientific knowledge and activable tools produced by RHCCS exist in a context and depend on it. This hypothesis brings the necessity to keep track of context where scientific knowledge and activable tools are produced.

Hypothesis 4: the building of an instrument is incremental until this instrument is good enough to be published. This hypothesis leads to the need to date the instrument versions in order to keep track of its evolutions.

Hypothesis 5: the field results and the evolution of the scientific knowledge can lead to a change in the research question in order to align the instrument with the academic, technical and societal contexts. It is thus necessary to capitalize on field results to explain changes in the research questions.

4.2 Validity and value criteria for THEDRE

We conclude the description of our epistemological posture with the value and validity criteria that need to be defined to assess research quality. It allows managers to identify an improvement or degradation in the process. A criterion is a chosen information, corresponding to a phenomenon, created to observe its evolutions regarding quality goals. Criteria are based on indicators, which can be events, observable measurable and calculated facts,. Indicators will be used to follow the research process and to guarantee the high quality of data collected during the process.

For the value of the scientific contribution, we use 2 criteria based on those defined by the pragmatic constructivism:

1. The quality of the construction: it is related to the adequacy of an activable tool to the users' needs and practices. Users are involved to build and to evaluate activable tools. These activities are tracked and some indicators measure its success.
2. The research contribution: in RHCCS, research can contribute to a generalization or to a refinement of some scientific knowledge.

The two criteria concerning the value of the scientific contribution rely on process management and on indicators monitoring this process.

For the validity of the scientific contribution, we use 3 criteria based on those defined by pragmatic constructivism:

3. Data multiplicity: our method, THEDRE, relies on a large diversity of data collected particularly during experimental steps. They can be either qualitative or quantitative [16], [17], [18]. They can come from different sources. They can be pre-existing data (e.g. from previous studies) or data to produce.
4. Data reliability: Volume and quality are two necessary elements to identify a relevant contribution. Indicators are used to measure them during the process.
5. Testing: it happens during the experimental steps when an activable tool is tested by users, in laboratory or in situ, during a short or a long period of time. Experimental steps are designed thanks to experimental protocols, which keep tracks of the research activity and guarantee the quality of the experimental approach.

The three validity criteria concern the experimental steps to build and to evaluate activable tools with users. So we recommend the use of monitoring indicators for the experimental subprocess and data quality indicators for the data produced.

5 THEDRE: a traceable research process

The value and validity criteria of the epistemological posture require both tools to manage process and indicators to monitor data and to ensure data quality. So we base our proposal on a quality approach based on the Deming's wheel.

5.1 Continuous quality improvement supported by Deming's wheel

Continuous quality improvement consists in a continuous effort to improve organization processes, services and products. The effort can focus either on small increments at regular time intervals or on a brand new improvement. Concretely, everything that happens during a process must be tracked to make an assessment of the process and to improve it. One of the most popular approach for continuous quality improvement is the Deming's wheel which guides the process improvement [20]. It is composed of four actions: Plan, Do, Check, Act (PDCA): Plan – prepare and plan what will be done; Do – realize what is planned; Check - Study the actual results and compare against the expected results (targets or goals from the "PLAN") to ascertain any differences; Act – Decide on follow-up: stop the process or iterate. This decision must be based on precise information called indicators.

6 Use of Deming's principles (PDCA) for THEDRE

In our proposal, we use the Deming's wheel to structure the research process. So our process, THEDRE, is structured following 4 cycles (Fig. 1) involving three kinds of actors (researchers, developers and methodologists) : Plan for research planner, Do for making developments and conducing experiments, Check for assessing results and Act which allows researchers to construct knowledge regarding assessments and to take the decision to start a new cycle or to communicate on results. To illustrate these four steps, we will consider the creation of domain specific language developed in the context of a French national project[1], a language for gardeners' applications. The language and its supporting tools must allow gardeners to adapt themselves their applications. The research is related to end-user programming as we expect gardeners' to define their adaptation rules. So more precisely, the THEDRE process is structure as follows:

- **PLAN:** it focuses on research construction; it sets targets to achieve and it pilots actions concerning development, experiments, and communication. During the first cycle, the research question and the experimental targets must be set. During the other cycles, the research question can be refined and other experimental targets can be defined. In the example of the adaptation of gardeners' applications, the global research question is related to end user programming: "what are the appropriate tools to allow gardeners to adapt the interfaces of their business applications". The activable tool is decomposed into 3 components: a definition of the business concepts (i.e. a dictionary of concepts), the features to adapt applications (which kind of adaptation is acceptable), and the specific users interfaces (e.g. gardener wear gloves when he interacts with his mobile phone).
- **DO:** it focuses on the development and the experiments to carry out, to build and to assess the research instrument. It corresponds to the THEDRE "Experiment" subprocess. In our example, a prototype of applications for gardeners must be built and several experiments are designed. The first one aims at identifying the business concepts. So a first version of the dictionary of concepts is produced.
- **CHECK:** this step aims at assessing the experimental results and at controlling targets. Researcher checks whether the research targets are achieved. This step is named "Control" in THEDRE. For the gardeners' example, the dictionary of concepts and the way it has been produced are evaluated.
- **ACT:** during this subprocess, some scientific knowledge is created from the experimental results and its limits. It is time for the researcher to make a decision about the continuation of his/her work on the research question and about communicating results. Depending on these answers, another PCDA cycle can start. The "Act" step of the Deming's wheel corresponds to the THEDRE "Building and decision» sub process. For instance, in the case of the gardeners' applications adaptation, the researcher decided that the dictionary of concepts was not significant enough for a publication and that other cycles were necessary, at least to define the features for adaptation and the user interfaces.

The PCDA cycle helps us to identify the THEDRE main subprocesses. For a more precise monitoring, sub processes are divided into blocks, which correspond to groups of tasks. A more formal description of the THEDREs' concepts is proposed in [19] with the definition of a domain specific language.

[1] ANR MOANO http://www.agence-nationale-recherche.fr/?Projet=ANR-10-CORD-0024

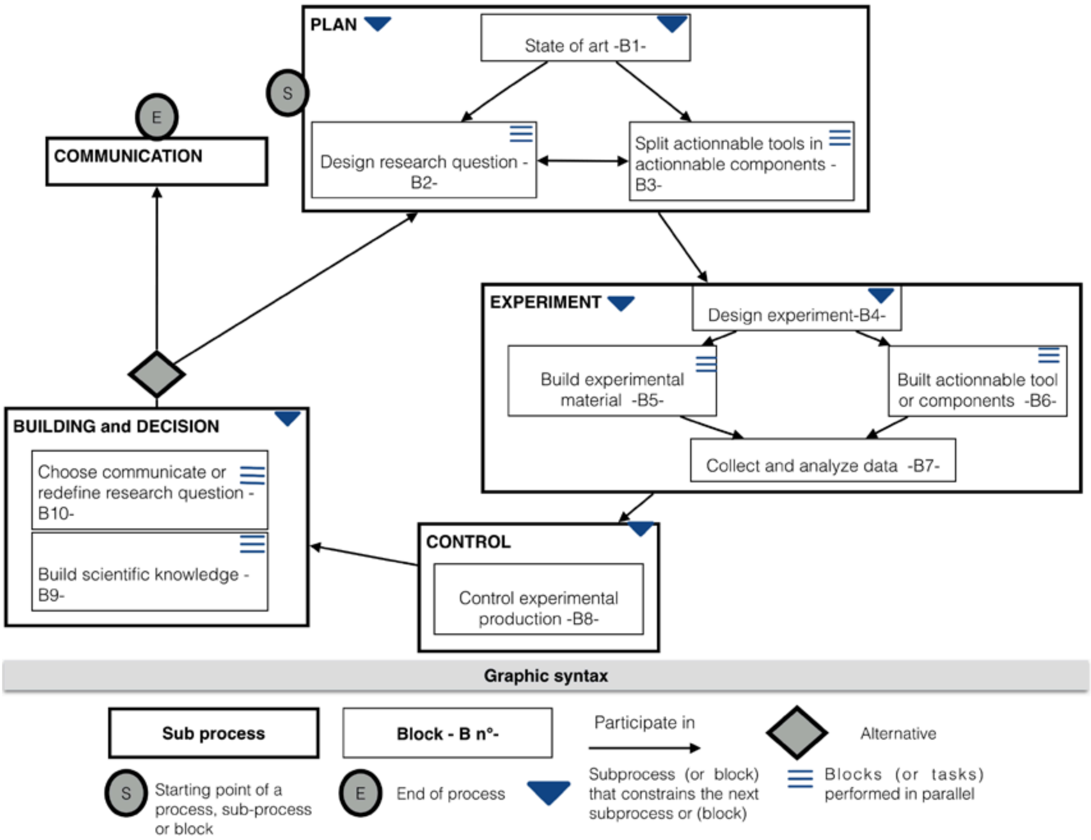

Fig. 1. THEDRE managed by a Deming's wheel

The use of the Deming's wheel also provides the opportunity to improve the research actions planned at the beginning of each cycle. This structure allows us to cover the two criteria related to value: 1) the quality of the construction is evaluated during the "Experiment subprocess", if it is not good enough, a new THEDRE cycle is realized; 2) The scientific contribution is built and evaluated; it can be refined during several cycles if necessary. Moreover each block is tracked during the process and some quality indicators are measured to monitor the research process. These indicators measure not only the process activities but also their production (deliverables, knowledge, etc.). The next section describes these indicators associated to the THEDRE process.

7 Quality indicators for the process for data quality

Firstly, we present 3 kinds of indicators to keep track of the research process and secondly indicators dedicated to data quality. These indicators characterize the research validity criteria in the epistemological paradigm. They must evaluate the research contribution, the quality of the construction, the multiplicity of data, the reliability of the data and the testing on the field.

Indicators for process monitoring. For continuous improvement processes, the ISO standard 9001 (revisions 2015) proposes indicators to evaluate products performance. In THEDRE, we propose three kinds of indicators: 1) "steering indicators" which guide the process, 2) "activity indicators" which report on activities during the process, 3) "results indicators" which evaluate the process deliverables. The standard being aimed at industrial production, we redefine these three types of indicators to better suit our RHCCS context.

- **Goal indicators.** They correspond to the "steering indicators". They allow researchers to follow their research work evolution and to improve the research instrument. In the PLAN subprocess, researchers define goal indicators, which correspond to their own expectations before publishing. At the end of the Building and decision subprocess, goal indicators allow researchers to control both the scientific contribution and that the activable tools are successful enough to be communicated or if a new cycle must be started.

- **Activity indicators.** They inform researchers about the tasks realized into THEDRE subprocesses or blocks. These tasks can concern the scientific knowledge, the activable tools or one of their components. Activity indicators can have boolean or numerical values such as the number of users interviewed, the number of relevant publications read. These indicators, which measure activity volume, can evolve over the process. For instance the number of relevant publications read will increase all along the research cycle.
- **Production indicators.** To support researchers during the whole process, guides are proposed. For instance, the "brainstorming guide" helps to elaborate experimental protocols or to synthesize experiment field. The use of guides will give rise to deliverables in their corresponding blocks. Production indicators check that the planned deliverables (e.g. the experimental protocol, data file) are produced. They constitute a check list.

Goal, activity and production indicators are related to the traceability of the THEDRE process. Researchers have to define their own indicators based on our recommendations: for instance, we recommend in the "Design experiment" block to produce an experimental protocol, but researchers can decide to prefer a testing procedure. Goal indicators are designed to measure the research value: they define the expectations in terms of quality of the construction and scientific contribution. Activity and production indicators allow researchers to ensure the quality of their research implementation by measuring activities and deliverables. So they contribute to the validity of research.

Indicators to control data quality. They also permit to achieve the validity criteria of our epistemological posture. They are concerned with data multiplicity and reliability.

Our problem here is to ensure the quality of the data produced during the "Experiment" subprocess. With this goal, we use Berti-Equille's work [21], that proposes 4 approaches to control data quality: (1) preventive, (2) adaptive, (3) corrective and (4) diagnosis. The preventive approach permits to make controls before data production (e.g. a test of a sensor before its use in an experiment will ensure that real time data are correct). The adaptive approach is based on the verification of data at real time (e.g. if a sensor gives absurd data, it can be calibrated again). The corrective and diagnosis approaches are realized after data production. The corrective approach includes some corrections related to the field, addition of missing values, removal of duplicate entries etc. The diagnosis approach includes the comparison with the field and the management of data describing data i.e. metadata. To be operational, these 4 approaches must be coupled with quality indicators. Di Ruocco et al. [22] define ten indicators (relevance, temporal precision, accuracy, accessibility, interpretation reliability, uniqueness, coherence, conformity to a standard, completeness, consistency). In THEDRE, we use the preventive approach to control data production; the diagnosis approach to evaluate data and the corrective approach to correct them. We do not use the adaptive approach dedicated to real time data capture and correction. So to qualify data, we use 8 out of the 10 criteria defined by [22]: relevance, temporal precision, accuracy, accessibility, interpretation reliability, uniqueness, coherence, conformity to a standard. We do not use completeness and consistency, as they are specific to database concepts. The use of these technics ensure data reliability before experiments with the preventive approach and after with diagnosis and corrective approaches. The 8 data quality criteria provide guidance to evaluate data after their production. Thus, they contribute to ensure data reliability.

Indicators inside the THEDRE process. Indicators are related to blocks (i.e. consistent parts of a subprocess) in the THEDRE process. In each block, activity and production indicators are proposed. Goal indicators are defined in the PLAN subprocess (the second block "Design research question" (Fig. **2**)) where the research question is designed, in the Experiment subprocess. During the experiment subprocess, they take part of block 4 when data collection is defined, including data to produce goal indicators, of block 7 where these data are collected and analysed and of the block 8 where goal indicators are used to control the experimental production in relation with research objectives. Preventive approaches for data quality are conducted in block 4 and more precisely during the task “define the range of possible values”. Diagnosis and corrective approaches are conducted in block 6. As an example, let’s consider the “design experiment” block of “Experiment” subprocess. It is composed of seven tasks (Fig. 2): T1: “Share between internal actors the added value of research”. This task allows internal actors to well understand the research objectives; T2: ”Define goals of experiment”, all actors collaborate to define precisely the experiment objectives; T3: “Write question or hypothesis” in order to precisely define data to acquire during the experiments; T4:”Identifiy measures and data to produce” where experimental data is produced; T5: all actors “determine ranges of possible data values”; T6 whose objective is the choice of the method for data production; T7 which defines the measures and data to compute goal indicators. In this block, three guides are provided, “build an experimental protocol”, “choose the data production methods/logigram”, and “formalize data quality indicators”. Its deliverables are the experimental protocols and the list of measures to calculate goal indicators and to ensure data quality. The activity indicators are: “having written the experimental protocols”, “the number of experiments designed”, “the number of meetings between the research actors”. The production indicators control if the two deliverables, experimental protocol and list of measures, exist.

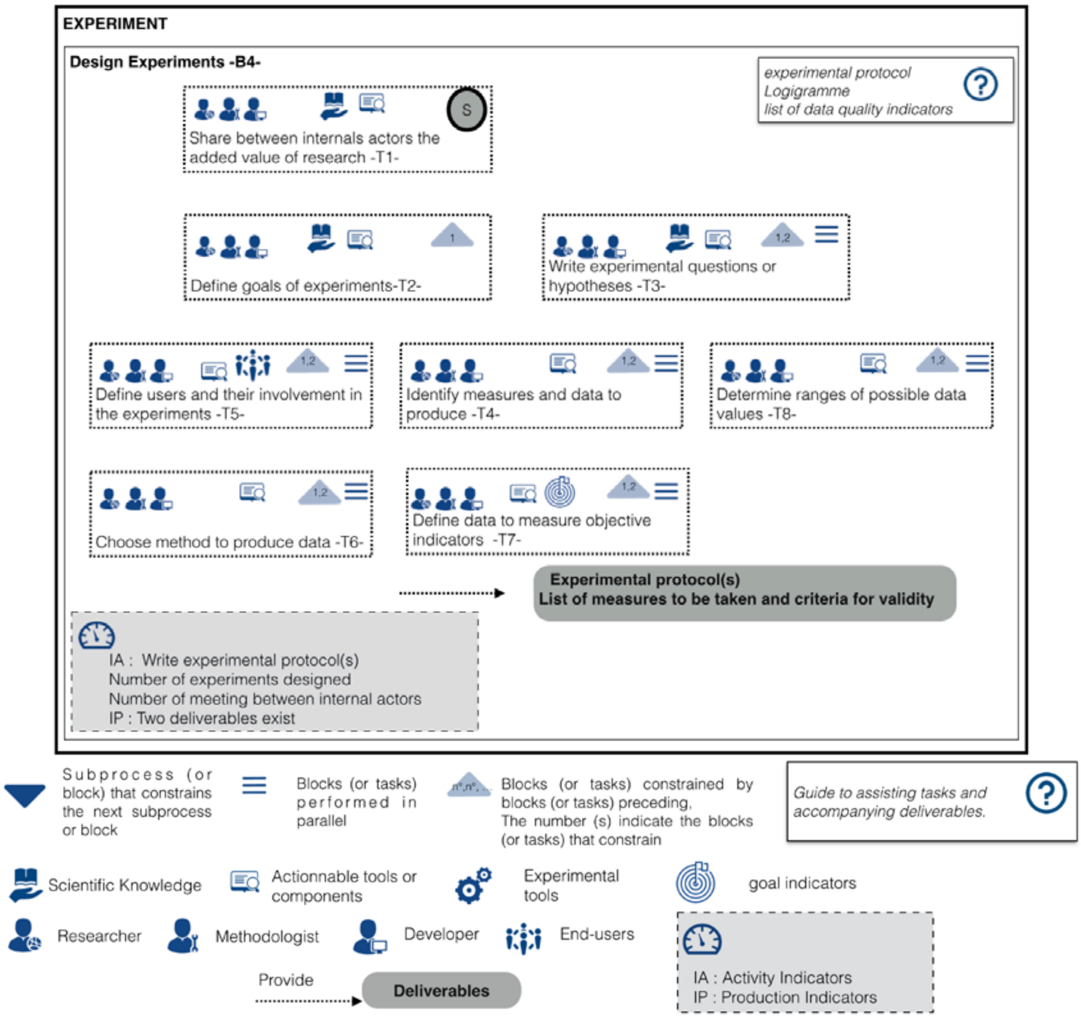

Fig.2. Block ‘Design experiment’ of the sub process « Experiment » and graphical syntax.

These indicators are identified to better guide research. They are related to (1) the process monitoring for the research value and implementation quality, (2) the validity (multiplicity and reliability) of data produced by experiments. The different kinds of indicators (goal, activity, production and data quality) allow us to fully take the value and validity into account while producing a scientific knowledge.

8 THEDRE construction and evaluation

The construction of THEDRE was based on observations from many RHCCS works. It has evolved and has been evaluated as it is reported in this section.

9 Construction of the THEDRE method

The THEDRE method has been built with a participant observation method [23]. During 10 years, we actively participate to the elaboration of experimental protocols in order to answer researchers' questions concerning methodological tools. We thus identified communication issues between researchers, developers and methodologists, which led us to propose tools for helping them in the design and implementation of experiments. THEDRE has been designed from a pragmatic approach founded on the RHCCS actors and their context of work. It has been built from the observation of 29 research works, mainly PhDs theses, in several computer science laboratories in France (Grenoble, Lyon, Paris, Le Mans), in four RHCCS domains. In Information Systems, six works from 2009 to 2014 have mainly allow us to design THEDRE [24],[25],[26],[27],[28],[29]. Firstly, these works have shown the need to have guidance to define precisely the research needs and to communicate with people who collaborated to design experiments. Secondly, they put in relief the necessity to define an epistemological posture to lead research in this domain, which required us to define value and validity criteria for the epistemological posture. In Technology Enhanced Learning (TL), we can keep 2 works [30],[31] that allowed us to refine guides produced in the Information Systems domain and to propose social and human science tools for data production in RHCCS. This benefit concerns la multiplicity of data, because we proposed to adapt data production tools to RHCCS and thus to provide several different means to produce data. From our work in the domain of Human-Computer Interaction [32], [33], we introduced qualitative approaches that are rarely used and merely unknown data analysis methods. These contributions answer the need to have several different measures and analysis tools in order to achieve the criteria of data multiplicity. Lastly we followed a work in the domain of multi-agents for robots [34]. It allowed us to test THEDRE all along this PhD work.

10 Evaluation of the introduction of the Deming's wheel and its indicators

The evaluation of THEDRE focuses on its main contribution for traceability. This is why we only report here elements related to the introduction of the Deming's wheel into the research process and its indicators. The evaluation of THEDRE was conduced with 20 researchers during workshops about research methodology for PhD students. It happened at the Laboratory of Informatics of Grenoble in January 2017. The goal is to collect researchers' opinions about the THEDRE utility and usability. Our first hypothesis (H1) is that the THEDRE process described as a Deming's wheel is useful and usable; our other hypotheses concern indicators: (H2) activity and production indicators are useful and usable; (H3) goal indicators can be identified by researchers during the early stages of their research. The activable components to evaluate are: 1) the global process (Fig. 1), 2) block 1 "State of Art", block 2 "Design Research Question" and block 4 "design experiment" with their traceability indicators. The data collected are qualitative.

Users found that the cycle representation is useful for leading research when the research question can "evolve with readings" and where "experiments can make the research question evolve". It helped researchers to understand that "research is an iterative process" and that "it goes ahead by steps". The decomposition of subprocesses into blocks and tasks appeared as interesting for researchers to guide them: "I would have liked to know this decomposition and this information at the beginning of my PhD, I would have lost less time"; "this structures well the work". The guides to help in writing deliverables provided at each block were considered as useful. Users were able to create an experimental protocol. However there was a need to adapt the guides to the different RHCCS domains. Activity and production indicators were judged interesting to have a check-list, “to avoid forgetting anything”. But the proposed list must be adapted to domains. For the goal indicators, users had some difficulties to identify them: “it is the role of my supervisor to define them”, “in the 1st year of my PhD, I don’t see what I can propose as indicators”. However, this reflexion about goal indicators allowed one PhD student to find new measures to evaluate his contribution. These experiments showed the interest of basing our proposal in a quality improvement approach.

11 Conclusion

We presented THEDRE a method to lead research in RHCCS that has been built from 29 works in human-centred computer science. This method, situated the constructivism pragmatic posture, proposes a formalized process to manage research with tools from quality management. The formalization of the process allows its actors (researchers, developers and methodologists) guidance at each step of the research process. THEDRE also has the advantage of offering indicators to keep track of the process and to ensure the validity of data and consequently the one of research results. Some experiments to evaluate the method showed its interest. To make it more usable, we are currently developing a web application, for documenting the method in order to allow efficiently navigating between activities, giving access to their corresponding guides. In future work, we will investigate whether more specific value and validity criteria must be defined within the RHCCS domains. Indeed, the definition of the validity and value criteria from J.M. Avenier [14] must now be fed from experimental fields.

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