Analysis of Collaborative Design through Action Research: Methodology and Tools

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Abstract- **Analysing collective design activities is a complex task, especially in a context that involves the remote collaboration and/or multidisciplinarity. To support such an analysis, this article describes a dedicated process, instrumented by tools that can facilitate the data acquisition and visualization, and implemented in various contexts of higher education. The method presented here enables to cross-reference the two aspects of a collective activity: the process and the content treated by a group. The method offers the possibility to analyse different types of collective work configurations with a high level of flexibility that leaves the possibility to the researcher to update his/her analysis criteria even during the observed activity.**

Keywords- collaborative design; methodologies and tools for collaborative activity analysis; visualization of collaborative processes; collaborative action-research project.

I. INTRODUCTION

Design and construction projects result from a complex collective activity involving several skills, starting at the earliest stages of the process [1]. These skills emerge from the fields of architecture and engineering, naturally, but also from the fields of ecology, sociology, and ergonomics, to name a few [2]. If all these skills need to be united, it is in response to strong competition, increasingly coercive qualitative and regulatory requirements, and short deadlines [3]. To address these real market conditions, design agencies and construction companies are looking for skills elsewhere, and adapt themselves as well as possible to this new context, without necessarily being prepared or equipped beforehand. This is why, today, it is important to fundamentally rethink training for careers in design (architecture, engineering, industrial design, etc.) to prepare future designers for this complex collective activity [1,4].

Indeed, this training is conducted, usually, over 3 to 5 years and is founded on project-based learning. This project-based learning is of course complemented by theoretical coursework that allows students to approach a range of areas necessary to master design. When these students work in teams, they need to manage their activity as a group, define each person's duties, coordinate, build agreements, and negotiate [5] Managing their project turns out to be complex to handle for novice designers as they continue to evolve in the context of ongoing learning and in one following an exploratory process. In this process, which is difficult to break down, they must specify both the functioning of the object to be designed and the means to be implemented. Faced with the difficulties of students working together, understanding a complex exploratory process, changing assumptions, and gaining perspective on their own design and collaboration activities, we ask ourselves the following question: could design be teachable in a format other than "project workshops"?

Without questioning the relevance of project-based learning, which is perfectly adequate for understanding design, we aim, in this article, to put forward a new training style created for design. Our approach, designed to be analytical and co-constructed, is to rethink collective activity in design and thus help the learner, whether Master's students or professionals, to gain perspective on their own activity in expression with others'.

In the aim of defining our own pedagogical approach, this article will first present a state of the art of commonly implemented approaches, to comprehend collective design activities. Then we will discuss our own approach in more detail and its general methods through the description of a training framework, called "workshop +". We follow by defining the four stages that this comprises, as well as the various methodological, theoretical and analytical tools put into play. We will subsequently list its assorted integrated applications, implemented for varied advanced design training sessions. Finally, experience feedback, contributions, limitations and perspectives of this teaching approach will be discussed, drawing conclusions from four years of its implementation in both academic and professional contexts.

II. BACKGROUND TO THE APPROACH

Group activities have been the subject of much research in psychology, ergonomics and cognitive science, for the purposes of modeling such activities [6]. These models are based on two synchronization modes: cognitive, referring to the construction of a context of shared knowledge; and operational, referring to the distribution of tasks among collaborators. These synchronizations are designed to build awareness that allows collaborators to interact with their environment and with the group of participants [7]. The role of common ground is crucial here because it enables each person to share their particular skills and to acquire new skills, to be able work with others [8]. Various studies have also highlighted the complexity of these activities, which varies according to the number of participants [9], the subject

of the activity [10] or the time and space in which such interactions take place [11]).

Given this variety of configurations involving multiple participants, diverse methods of technical support have been proposed, which may target particular tool features as well as the organization of assigned workgroups. These forms of technical support come under the scientific framework of CSCW, "Computer Supported Cooperative Work" [12] and more specifically CSCD, "Computer Support for Cooperative Design", which focuses specifically on collective design activities [13].

Our alternative education proposal resides in this scientific field, focusing on instances when different present or remote participants work together around the same design subject. This phase is one of emerging ideas, choices and negotiations that ensue through interactions and artifacts shared among participants; it is even more difficult to understand, observe and analyze as it involves multidisciplinary skills. The original approach that we present in this article is driven by this perspective gained from stepping back from a complex collaborative activity.

Let us begin by contextualizing our approach in relation to others already destined for teaching design, then we will define the type of protocol that we have chosen and the analytical point of view that it is built upon.

A. Selecting an approach

Dedicated to advanced end-of-degree learners (second-year Master's or Research Master's students) or professionals questioning their collaborative design activity [14], the approach proposed here is complementary to that of the conventional workshop. It was elaborated to be collective, with the goal of focusing the attention of the learners on the process rather than on the object to be designed, leading them to a "meta" reflection on their own design process and collaboration.

Involving the active participation of learners in the specification of self-analysis activity, our approach lies in the scientific fields of participatory approaches.

Participatory approaches to research are multiple but strive for the same goal, that is, to associate an experience, an action, practice and analysis [15]. "Action research" is one such approach that breaks away from conventional scientific approaches, which systematically separate action from its analysis, collective practices from their theoretical elaboration [16]. Its main target is to manage the concerns of participants faced with a situation, by the intervention of research aimed at developing a shared understanding of the situation [17]. It is deemed "collaborative" when all participants (researchers and practitioners, observers and designers) attempt to co-construct new meaning relative to their activity [18]. This co-construction is created through the synergy of their views, but also through a reflection on one's own action with respect to others' [19]. According to Desgagné [20], this approach is based on a reciprocal relationship of self/co-reflection, self/co-criticism and, therefore, self/co-training, with oneself and with other collaborators. The implementation of "participatory action research" is mostly seen in the professional training of teachers, child welfare, specialized coaching, or territorial development but is still rarely used in the design field [21]. Integrating this into our approach encompasses a participatory protocol involving several participating designers, observers, and researchers. Its educational purpose is not to assess the value of the design project itself (as is the case for project workshops), but rather to describe the process that brought it about. It does not impose a method of design; instead, it investigates how it is possible to observe, analyze, or break the process down, in order to better perceive the collaborative activity and the complexity of interactions involved.

Our premise on design activity considers it to be one that is complex and difficult to break down, and one whose outcome is first contemplated, negotiated, valued, challenged and co-constructed before even coming into existence.

Two questions arise: How should we speak about the design process? Plus, how it is negotiated and co-deliberated by the group? To answer these questions, original tools have been created to query design and collaboration. They have been defined so that all designer/observer/researcher participants co-construct integrated meaning and decide all actions which result from it [22, p. 83]. They propose data harvesting protocols, processing and analysis of the observation data most appropriate to this analysis approach and help to collectively understand the complexity of the components of a collaborative design activity.

B. Defining the protocol

Since the 1990s, many studies have endeavoured to promote and assist collective activity. To summarize, we distinguish them as follows:

- those seeking to categorize and define collective activity [23];
- those focusing on the technical aspects of this activity [24];
- those concentrating on its social aspects [25];
- those concerned with developing human-machine interfaces, others with human-human interfaces, to assist collaboration [26];
- those developing methods and tools for the analysis of this complex activity in their real context or in a laboratory [27].

Focusing on the latter aspect to comprehend collective activity, one of the main data collection and processing methods for the analysis of collaborative situations is protocol analysis [28], which is generally intended for comments in controlled environments. This protocol analysis is based on two data collection methods: retrospective protocols and concurrent protocols. Each method can produce similar results for a coherent understanding of the problem-solving process, but they can also complete each other, according to research objectives [29].

Retrospective protocols. This protocol consists in asking the participant under observation, after (s)he has completed the activity, to choose elements representative of their activity, and then to describe them in order to better identify the specific features of their work, alone or in a group. It relates, therefore, to the study of design objects and

their components as distinct from the situations in which the former evolve [28, 30]. This approach aids, we believe, in changing the point of view of the designers regarding their design object by asking them to conceptualize their activity and to utilize their memory. It has been shown elsewhere that, although the stored information may rely on short-term memory, this cumulative data can provide relevant details for the research question [27] and the origins of the decisions for the resolution of various problems [31]. Self-confrontation may also be another approach for analyzing an already completed task [32]. This consists in requesting a participant to perform a self-assessment of his or her own work processes (alone and/or with others) from footage of their activity [33]. However, we find this other method requires too substantial an investment by the participant in terms of time and research involvement.

Concurrent protocols. This protocol consists in asking the participant to verbalize his or her thoughts out loud while working on a specific task ("thinking aloud" [34]). These thoughts are then transcribed, coded and analyzed by the researcher. This approach rests on the assumption that the verbalization of thoughts during the problem-solving process does not affect the process [28]. Other researchers do not agree with this assumption, however, and consider "retrospective protocols" to be less intrusive in the process, as the protocol is put into practice following the completion of activity [35]. Yet, as part of a collective activity, the interlocutors are naturally found obliged to communicate and verbalize their thoughts to work together.

Thus, we consider that the "concurrent protocol" is meaningful since it better approaches real conditions of the activity and its context. Taking the activity's real context into account reinforces the ecological validity of our advanced training and does not exclude the social processes, teamwork and communication that constitute the reality of daily work.

C. Application to a twofold analytical approach

Analytical approaches are varied and may result in qualitative or quantitative results. As taking a step back seeks to be constructive and objectifiable for the learner, it is necessary to achieve a certain degree of precision in the processing and analysis of data observed. Analytical methods known in the literature are generally based on a segmentation system which, according to Nguyen et al. [31], can be oriented according to the process or content.

Process-oriented segmentation. This approach makes it possible to break the process down into several sequences related to the participants' intentions and to identify the time spent on each of these sequences, as well as the correlation between them. As proposed by Gronier [36], the COMET method [5] is used to describe the main phases of identification and argumentation of a problem. The coding grid, developed for the specific analysis of viewpoint confrontation processes in concurrent engineering [37], allows researchers in turn to draw up a tree of proposals and verbal interactions between collaborators' work. The analysis carried out by ALCESTE word processing software [38] also makes it possible to structure the information involved and shared by participants to solve a problem. Although all these methods complement each other, this "process-oriented segmentation" approach has nevertheless been criticized in some studies because it does not focus enough on content, i.e., on the problem addressed, on documents or even on annotations produced by the participants during the activity under observation (39).

Content-oriented segmentation. This approach makes it possible to complete the one above since it is specifically concerned with artifacts (e.g., pictures, notes, references, and models) and enables us to examine the cognitive interaction between designer and artifacts [40]. One of the best-known methods among these is that of Gero [41], which offers an encoding principle, named FBS, dependent on the functionality of the object ("Function"), the behaviour of participants ("Behaviour") and the collaborative structure ("Structure"). The author there considers design to be a series of transformations of the model's functions. Brassac and Gregori [42] proposed, for their part, a clinical approach which focuses on real activity and its various interactions by studying discursive productions, gestures, graphical representations and conversational sequences. This approach, according to their research [42], allows not only speech acts to be classified, by breaking them down into sequences and sub-sequences, but also the conversational dynamic between collaborators to be illustrated. In a similar vein, through the use of ethnographic studies, Boujut and Laureillard [43] immersed themselves directly into a real industrial environment and proposed a method of "action research", analyzing the framework and introducing new tools to aid in collaboration.

III. DEFINITION OF ADVANCED TRAINING: WORKSHOP+

Relative to the state of the art examined above, our approach lies clearly in "participatory action research". In the workshop proposed here, we group together supervising researchers and learners playing either the role of designer or of observer. All participants involved in this process are thus "engaged in a critical, dynamic reflection upon a situation that appeals to them" [22, p. 78]. So they are all active participants in the experiment. They participate together in data collection as well as in its processing and analysis by the co-construction of shared meaning around a collaborative design activity. In this context, the approach chosen was that of "concurrent protocols", focusing on the process and its evolution over time ("process-oriented segmentation") as well as on the design draft examined and on the interactions involved in building it ("Content-oriented segmentation").

By taking an interest in advanced university courses as well as in professional training, the challenge of our approach lies in the context concerned with our workshop+. It can take place either 1) in an educational context of project execution, possibly with large amounts of onerous data to be analyzed, or 2) in a professional context that, for privacy reasons, does not allow audio and/or video data to be recorded to process and analyze later, data being based on verbalization and transcription. This consists in confronting the participants with their (oral and graphic) interactions with the goal of self/co-analyzing and self/co-understanding negotiation and collective decision-making processes. This

description is carried out qualitatively, in our approach, and also relies on quantitative data visualizations questioning various criteria involved in the specification of collective activity. It is therefore crucial to avoid the possible dichotomy often found in conventional research practices where researchers collect data by themselves, reframe their observations, analyze and then present them to the subject observed, once the entirety has been handled.

Rather, this co-construction of meaning regarding the activity and this moment of taking a step back to reflect are, as a result, performed here with the designer, not on the designer. While a traditional approach could ensure greater objectivity faced with the situation under observation, in the training contexts involved in this study, cross-feedback from that step back is given particular preference in our workshop+. Yet this does not prevent a scientific approach from being taken, so as to objectify some of the hindsight on the design and collaborative activity, both by designers and observers. Thus, thanks to specific methods of observation, note-taking, implementing a common coding grid, scientific analysis methods in the humanities, and analytical tools for data processing, our workshop+ seeks several objectives regarding the participants:

- to co-construct a reflection on their collaborative design activity,
- to develop their critical thinking by dealing with differing points of view,
- to structure and enrich mastery of their know-how and to support their conceptual strategy, and
- to start to take a step back thanks to an introduction to research practices in design.

The pedagogical approach proposed here in workshop+ is likewise divided into 4 stages:

- Step 1: experimentation via role-playing games, involving designers and observers with predefined missions and note-taking grids;
- Step 2: the transcription through the co-breakdown of the process and co-reporting of the actions observed and experienced by observers and designers;
- Step 3: data coding and processing via the co-construction of meaning for actions' specification;
- Step 4: analyzing and weighing up results through stepping back and co-defining negotiated knowledge, resulting in a co-modification of the action through mutual feedback.

For each of these steps, we will examine below the implementations and the targeted objectives, and will describe the different tools implemented to allow participants to begin reflecting upon their activity.

IV. FOUR STEPS OF WORKSHOP+

After a brief introduction regarding our training's objectives and motivations, the training begins immediately with experimentation, which consists of a two-hour collaborative design situation.

A. Step1 - Experimentation

Implementation. Learners apply an experimental protocol defined in advance according to a method dictated by the context (short vs long integration). The definition of this protocol is essential to ensuring the smooth running of the workshop+ and to guaranteeing its integration into a collaborative action research approach. Hence, each participant belonging to the same workgroup is given a role that he will keep throughout the workshop+: either as a designer (3 designers minimum per group), or as an observer (number defined by number of participants in the workshop+). Designers are arranged in a predetermined seating arrangement and face the design brief given to them. Observers take notes "on the fly," with respect to a common time reference given by a shared stopwatch. Each observer has a mission, precisely defined by a card dealt before the start of the experiment (Figure 1). This task may involve one of the following:

- a general observation, where the observation criteria are not dictated by the experimenter: the objective is to build a qualitative observation that takes into account the specificity of the situation observed;
- a detailed observation, structured according to a grid predefined by the experimenter: the aim here is to systematize their observations to make their data more explicit and more easily quantifiable.

The mission of each participant is only known by other observers after a minimum training time to overcome the main limitation of "concurrent protocols." This is why it is important that observers be perfectly well-prepared, capable and motivated, and that designers gradually forget their presence. To do so, the experiment was divided into 2 phases. During the first half hour, observers respond individually to specific missions, ignoring others' missions. After 30 minutes, the session is suspended: all observers are gathered in a room away from the observation site, to learn about each other's missions and to confront their difficulties in observing. This phase allows them to stabilize and coordinate their note-taking strategies to resume thereafter in a more coherent manner, adapted to the context observed. Then follows the second phase of the experiment, during which the observers continue their note-taking, whether general or specific. Designers, for their part, still do not know what the observers are scrutinizing. It is indeed essential that designers not know what observers are watching for. Otherwise, the risk of influence on the designers' working practices would increase and could make the observation meaningless.

Objectives. Enforcing the protocol makes it possible to set certain variables in advance, such as the seating of the designers around the table, reference documents given, the tools at their disposal, etc. This imposed setup also allows participants to better gauge, afterwards, the influence of the situation and the context of the design process and collaboration between designers (namely in that designers are not made aware of what must be notified by the observers, so as to keep influence on their work to a minimum).

Methodological tools. The protocol is proposed so as to describe the collective design activity. Thus, note-taking grids adapted to multi-collaborator interactions were defined according to 4 observatory themes identified through mission maps:

- Theme 1. Observe collaboration: each designer is assigned an observer whose mission is to focus on their actions while working (or not) with other designers. With respect to a single time, the observer describes the interactions of the designer under observation vis-à-vis others and the space in which the designer is working (RIN 2012). The observer also notes the documents used by "his/her" designer, and the types of performances used by the individual during the process;
- Theme 2. Observe design: one of the observers is specifically assigned to monitor the design process and artifacts that are created therein and/or shared by all designers. He or she must specify, among other things, part(s) of the project concerned by the designers' action (e.g., the building entrance) and the documents used and/or created to work on the project;
- Theme 3. Observe trends: one observer is assigned to list and describe the different analogies, specific manifestations of emotion, occasional use of tools, etc., implemented by the designers during the project design;
- Theme 4. Observe freely: this observer's mission is to meta-analyze collaborative activity overall in the design process observed, relative to key moments that seem important to him or her to emphasize.

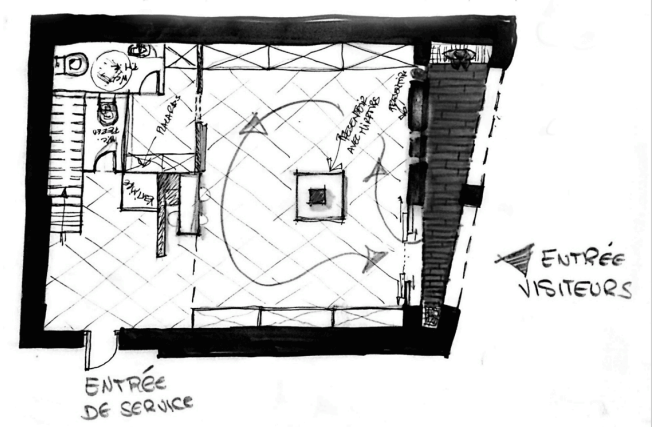
Theoretical tools. The workshop+ is introduced by an introductory course regarding the scientific approach, supplemented by a course sensitizing the learner to "how to do" rather than simply "doing". Once the designers have been informed of the program for the project to be designed, observers privately undergo training on note-taking techniques and on the relevance of complying with the protocol in the context of a scientific approach.

Analytical tools. At this stage in the workshop+, no analytical tool, outside the note-taking grids, is given to observers yet (Figure 1). Everything is taken down "on the fly" using a stopwatch made available to them and displayed to all participants as the one and only reference, easily recognizable by observers, and which will subsequently allow them to synchronize their observations.

B. Step 2 - Transcription

Implementation. During the transcription phase, the time marker has a significant impact. All collected data is first synchronized according to the predefined criteria in the note-taking grids.

During this data synchronization step, designers and observers come together to discuss their views and chronologically transcribe their experiences and observations into a single account. This mutual account of the collaborative process is thus built, in the form of actions, through a consensus among the various participants. By putting every action into words, observers break down the activity into moments of interaction; they then transcribe these into distinct categories describing the collaborative



Time	Key moment	Actions	Communi-cations	Actors' roles
0:10	*Sketch of the sale desk*	*A is drawing the desk with the help of B*	*A is talking to B*	*A as leader*
0:12	*Location of …*	*B is suggesting the … the entrance*	*Reference to document DB*	*A is listening*
0:15	…			…
0:17	…			…
0:21	…			…
0:27	…			…

PS MISSION CARD
Observer : process
Key moments
Please describe the key moments composing the observed design process.
Actions

Figure 1. Protocol, design product, mission card and note-taking grid

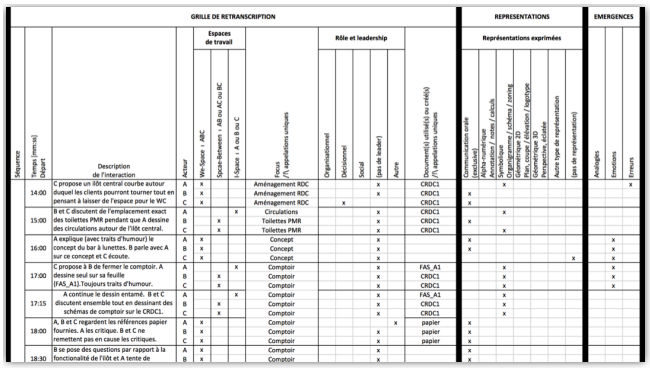


Figure 2. Notes taken converted to coded data

design process. The joint transcription process in words is already a first look back at the activity that took place. This transcript is carried out via a frame segmenting activity vertically according to a temporal reference to describe the process ("process-oriented segmentation"); and horizontally according to predefined criteria describing the content and specificity of each action ("content-oriented segmentation"): typology of action, workspace concerned, documents used, representations created, analogies observed, degree of object handling, degree of object abstraction, emotions expressed, etc. Each action is a testament to the design operations and collaboration implemented by each participant according to his or her viewpoint, relevancy and references. This action list is then segmented to split the process into several sequences. A sequence is thus a series of decisions, starting with the explicit expression of intent or of a problem that does not necessarily end with its resolution; rather, it may lead to the beginning of a new sequence that may or may not be directly dependent on the previous one. A sequence is composed of a succession of moments, these being composed of actions, representations and points of view (e.g., general layout > layout of ground-floor > layout of 1st floor > entry plan > etc.).

Objectives. This transcription step makes it possible to synchronize note taking and to set observers' viewpoints against designers' experience in a joint time description of the collaborative design activity (under the supervision of the researcher). In this step, each participant enters into dialogue with himself and with others so as to organize and specify the course of action for the activity observed. By setting each action into words, the participants negotiate and attempt to understand each other. This implies "leaving behind the implicit for the explicit", which sometimes involves a deconstruction/reconstruction of representations that participants had prior to their activity [44]. The transcript grid was defined well in advance by the researchers in order to provide a framework that will allow them, by a consensus, to collectively stop the main actions to be studied. It serves as a discussion framework for researchers/supervisors, for questioning certain defining criteria for the activity. This transcript grid later became a grid for reading and analyzing data for the whole group (designers/observers/researchers).

Methodological tools. The transcript grid (provided to observers with a structured observation mission) is composed of several categories (Figure 2). These categories are themselves divided into several exclusive criteria, as follows:

- description of the interaction between designers;
- identification of documents used or created by each participant;
- observation of trends: if an analogy, tool handling and/or a particular emotion was observed, for each participant;
- types of representation expressed by each participant (e.g., oral communication, notes, diagram, 2D drawing, 3D geometry, etc.);
- specification of workspaces for each designer: each designer working individually (I-space), two working apart (Space-between), or three working together in the same I-space (We-space).

Theoretical tools. A methodological manual is made available, defining all categories and criteria that make up the transcript grid.

Analytical tools. Automated formulas are inserted into the transcription file (.xls), helping participants to rapidly detect certain transcription errors.

C. Step 3 - Coding and data processing

Implementation. After synchronization, data is then transcribed collectively, to enable more accurate description of the evolution of the design project, the collective activity, and to enable increased accuracy of different analogies set forth by the designers. These criteria and categories stem from research and state-of-the-art presentations to students in theoretical courses associated with this workshop+ (see hereunder "Methodological tools"). Once encoded, the data is then processed by a tool called Common Tools (CT). CT is a web application initiated in the ARC COMMON research project [45] and developed by LUCID at the University of Liège. It allows all the encoded data to be viewed with respect to time, occurrences and specificities of each participant involved in the collective design process [1]. Visualizations proposed here concern the process as much as the content, by describing the temporal evolution of the participants' interactions and their implications on the mutual design object (Figure 3).

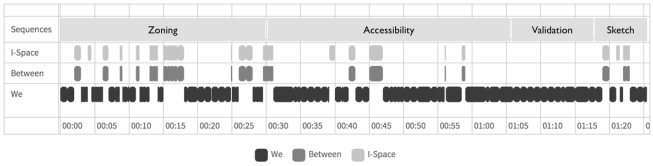


Figure 3. Example of visualization (timeline of workspaces) proposed by COMMON Tools

Objectives. This stage of coding and processing transcripts, by combining designers and observers, allows them to understand how to link their own observations with theoretical models, given in courses related to the description of collaborative design process. This approach therefore offers a second opportunity to step back and consider the process. Setting their acquired knowledge against what they observed during the experiment also gives learners the opportunity to challenge the transcription and coding grids provided by the supervising researcher. Learners can in fact redefine certain criteria or add new ones thanks to the flexibility of the grid and to the visualization facilitated by CT.

Methodological tools. For this third stage, new encodings complete the transcript grid: with respect to the design object (according to its degree of handling and of abstraction), to collective actions, and to types of analogies put into practice. Each encoding is divided into several criteria to detail the collaborative design activity more precisely. A methodological manual is provided, allowing learners to have the exact definition of each criterion.

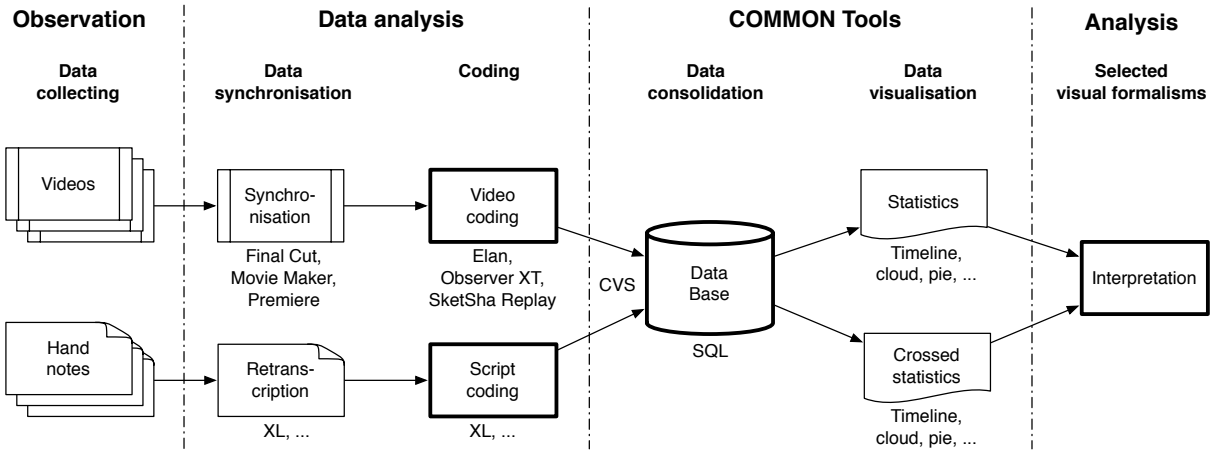


Figure 4. From data collection to processing by COMMON Tools for analysis purposes.

Theoretical tools. Based on this predefined experimental protocol, theoretical concepts to be called upon are introduced via course modules spread over the workshop+. Backed up by references from scientific design & cognition and CSCW communities, these modules present learners with the main concepts used in the workshop+: (1) design process models; (2) group activity specificities; and (3) the use of analogy in design.

Analytical tools. Provided to participants, the Common Tools platform performs data processing from the code frame (in .csv formats), transforming it into consolidated, quantified data (Figure 4). It then allows the user to view that data under an assortment of graphical representations (e.g, pie chart, stacked columns, timeline, crossing, clouds, etc.). This tool thus provides quantitative data visualization functions for different categories in the form of a panel of graphs (over 4000 graphs proposed by analysis). Each piece of data can be displayed by chart type, but also by participant or for all participants, by sequence or for all sequences, in occurrences or in duration. Trends, in turn, take the shape of dots in the timeline, to mark events occurring singly in the collective design process. The tool also allows two categories to be compared for advanced analysis of the complex collaborative design activity.

D. 4.4 Step 4 - Analysis and key results

Implementation. This final step marks the transition from description to interpretation. Here, all participants scrutinize the quantified data and choose the appropriate type of chart to affirm or reject comments made during the first instance of stepping back from the project. It allows them to integrate quantitative data, displayed via Common Tools, the relevant descriptive dimensions already having been identified qualitatively during transcription (e.g., communication strategies, types of sequences, forms of collaboration, body language, or interpersonal development).

Objectives. The objective of this stage is the mutual definition of the research questions specific to each experiment by observers and by designers, jointly. Here, all the participants also negotiate choosing the right graph style to give meaning to quantified results and to respond to questions. This step invites the group to query each other: what are our research questions? What do we want to put forward in relation to the collective activity and the design process we observed? How can we appraise our results? What can we take away with respect to what has been experienced/observed in the role of designer as well as of an observer? This step thus marks the third opportunity to step back, where the participants no longer focus solely on design analysis and collaboration, but also raise the question of the influence of the protocol on the functioning of the activity. This "metatheatrical" analysis concerns seating assignments designated by the protocol, the note taking grids and predefined analysis categories, as much as the approach itself to collaborative action research. In addition to the question, "How do designers collaborate and negotiate the project?" they examine, firstly, the negotiation process between observers for synchronizing their views and, secondly, their collaboration with the designers to set their observations against experiences within the same experiment.

Methodological tools. Introduced to the scientific process, learners apply social science analysis methods and learn to adapt the description of the facts to the interpretation of results, which they highlight by selecting relevant visual formalisms (graph styles) as visual data interpretation aids.

Theoretical tools. An additional course module presents learners with the typology of visual formalisms for the enhancement of scientific results (e.g., which to choose; how to read, describe and interpret them).

V. IMPLEMENTATION

Our approach was implemented in several advanced pedagogical frameworks for the analysis of and hindsight into design meetings in the form of workshop+. As discussed in the introduction, it acts as a complement to conventional project-based learning or to doctoral or professional training for teachers and/or design collaborators specifically interested in group activities.

TABLE I. CONTEXT OF IMPLEMENTATION

	Application context	Steps and analysis tools	Educational objectives
Short integration from 6 hours to 2 days	• 2nd Master in architecture, University of Liège • 1st Master Design, High School, Liège • International Design Research Workshop, Liège	• mission cards • qualitative analysis from note-taking • crossing observations and synthesis with pre-requisite knowledge	• construction of an experimental protocol • step back and on collective activity in design
Long integration from 4 to 8 days	• 2nd Master Architecture & Engineering, University of Liège • 2nd Master Architecture, University of Brussels • 2nd Master Architecture, University Ibn Khaldoun, Tunis • Master Research, in Ergonomics, University Paris 8 • Master Research in Design, High School, Tunis	• mission cards • qualitative analysis from freehand notes • crossing observations through a coding grid (xls file) • quantitative analysis and visual formalism with COMMON Tools • synthesis including theoretical coursework followed during the workshop	• introduction to scientific research • learning methods of collecting, processing and analyzing data • step back and on collective activity in design • considering the involvement of context in collaborative design activity

The fields of application involve architecture, engineering, design, ergonomics and project management.

Two workshop+ styles were proposed. These styles take into account the time allotted in the workshop+ depending on the context in which it is situated. Both styles were designed to train people to carry out a reflective, shared analysis of their design and collaboration process. However, they ranged from 4 hours to 8 days. Table I summarizes the characteristics of each, presenting their operational focus (regarding the time available for the workshop+), their pedagogical focus (regarding the learning objective targeted by teachers inviting us to employ this approach) and their theoretical, analytical and methodological tools, all complementary to each other.

At the end of each workshop+ each participant was asked to assess (anonymously) the activity's proceedings, its content and its interest relative to their academic and/or professional background. This assessment consisted of a questionnaire and 3 open questions. The questionnaire (imposing a scale of 1 to 5 on a criterion-based grid) included 12 questions concerning the modalities of the workshop, its relevance and the methodological, theoretical and analytical tools employed. The open comments were, in turn, related to the major contributions of the workshop+, the shortcomings raised and additional suggestions to consider. The following discussion will therefore be based on that assessment in addition to our qualitative observations made after four years' experience in implementing this activity.

VI. ADAPTABILITY OF THE COLLABORATIVE ACTION RESEARCH APPROACH

As outlined by G. Monceau [46, p.21], "not all participation in action research necessarily means collaboration, i.e., 'working together'." The approach proposed here was introduced to encourage progressive thinking, self-confronted, co-evaluated and co-constructed at the same time. Indeed, steps 2, 3 and 4 invite all of the participants (designers, observers, and supervising researchers) to describe their actions, through the transcript, collaborative encoding and analysis via imposed criteria. Trying to objectify all the activity into words by the interaction of various epistemological reflections, designers, researchers and observers converse, debate, look for evidence and challenge preconceptions. This progressive, fluid strategy maintains the co-construction of meaning as an active process, ensuring this triangulation between coding, analysis and interpretation of data. Although at first glance, these steps seem perfectly distinct (relative to the scientific approach described in the Section VII), they interfere with each other and also allow backtracking and a shared awareness of their activity's complexity. The keystone of collaborative action research is the participation of all collaborators (observers, designers and researchers) at every stage of the protocol: from the precise definition of the research question, to the collection, processing and analysis of data, up through the exploitation of results. Moreover, after having been implemented multiple times, the value of this type of approach is evident in a university curriculum for students learning their craft (Figure 5). More than 85% of them assigned a value greater than or equal to 4/5 for this criterion (1 = least important / 5 = most important). According to them, this work was not only the opportunity to study the activity of collaboration and design among multiple participants, but also to work together (as researchers, designers and collaborators) to find common ground on different concerted actions: "The challenge was at the time, above all, to agree on a single scenario at the start of transcription, to find compromises in order to construct a single reflection from many voices. Only this group reflection, based on consensus and the search for a common construction of what we could observe, has enabled us to comprehend and to be able to advance in our research." Thus emerges a dynamic way of thinking that promotes co-

construction of meaning in relation to both the situation studied and the activity examined.

However, to ensure such "thinking together", it is necessary up-front to query the purpose of this type of approach and its objectives for each participant. To begin with, participants' interests may diverge: the learners' primary goal is to question their practice, while for supervisors/researchers, the scientific investigation at hand is their core interest. Yet it is through the active relationship between learners and teachers, and the strong link with the world of practice, that the whole point of this type of approach emerges. One fosters the other through the development of a multi-referential framework. Indeed, all of the significance of this approach lies in this "metareflective" setting or *mise en abyme* ("observe a group activity to gain perspective on one's own activities" and "observe a group stepping back to co-construct meaning"). The product of stepping back from the activity here becomes co-constructed, without necessarily seeking to transform any one person's action, because it is not about differentiating identities or roles. Rather, it is necessary that the identities and roles of the participants remain distinct with a collective reflexivity and (new) knowledge and expertise that are co-shared/co-constructed in the work/research group. However, methodologically adopting a position on the border between "seeing the other as an object of study" (to maintain one's objectivity) and "identifying with the other" (to take into account the other's motivation) does not come easily to all.

Additionally, this point raises an ethical question, specifically in relation to the analysis and degree of validity. The description of the activity as actions, based on dialogue between researchers, observers and designers, can be questioned and its objectification challenged. Indeed, the collaborative nature of this action research promotes the establishment of a groupthink, capable of inducing an illusion of unanimous rationality and collective censorship (of oneself and others). This effect slows the emergence of collective intelligence and of a real step back from the activity.

This is why the role of the researcher and their supervising function are paramount here. Between "controlled activities" and "concerted actions", the supervisors/researchers must be fully aware of not only the contributions, but also the issues and limitations of this approach. They help to problematize the issue of "knowledge" and "expertise", to objectify it through the appropriate scientific approach and also to contextualize it in relation to a state of the art and theoretical courses prepared in advance. They not only serve the role of providing expertise in the analysis of complex activities; they also act as a partner, guiding reflection throughout the workshop. They strive to ensure that questioning should remain continuous and that hindsight be supported by co-defining questions and concerted actions. The researcher steps in here as a participant who cultivates self-learning and, by his or her point of view, enriches reflective, fluid thinking on the part of the whole group. Over 80% of participants also stressed the importance of this support in the group work mode, involving participants with different roles and courses alternating with well-equipped debriefing sessions.

However, this context creates an uncomfortable situation for the supervisor/researcher because they must develop their ability to support a group and to let go (as opposed to the test-tube effect of the laboratory, where the setting is completely under control), while taking into account both their theoretical and methodological expertise. As a result, the workshop+ serves to train both the professional researcher and the learner; consequently, it aids in rethinking what is typically a hierarchically-determined relationship, between learners in search of knowledge and teachers in possession of that knowledge. This hierarchical relationship has indeed proved its limitations in an advanced training context, where – from an educational perspective – reexamination, a forum for questioning and active thinking are favored, rather than mute listening and passive absorption of knowledge.

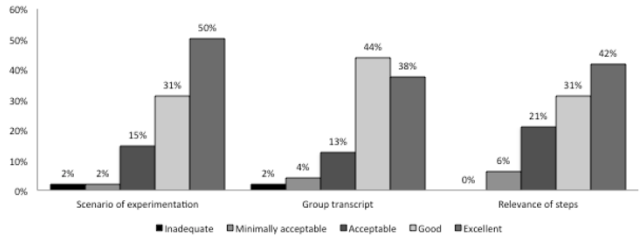


Figure 5. Value of workshop+ in the learner's overall education.

VII. INTEGRATION OF A SCIENTIFIC APPROACH INTO A "PROFESSIONALIZING" COURSE OF STUDY

- The primary interest of the workshop+ lies in heightening the awareness of a scientific approach in a professionalizing course. Indeed, the 4 steps that make up the workshop+ are highlighted in Figure 6 with respect to the main stages of a scientific approach. This figure illustrates the appropriateness of these steps with the demands expected of a classic scientific approach, while allowing different participants (researchers, designers and observers) to begin to step back to reflect and question prerequisites and theoretical courses taken, thanks to the following;
- the contemplation of similar studies that aim to model the complex activity of collective design: the research (supplemented data in the form of scientific articles) forms a theoretical reference frame that partially constitutes learners' state of the art;
- compliance with an objectified, rigorous and appropriate experimental protocol, based on the definition of operational working hypotheses and on the description of the facts in concerted actions (step 1, Figure 6): this first requirement makes it possible to see the impact of the situation and the context more clearly in the design and collaboration process among designers. Thanks to mission maps and note-taking grids, the student effectively takes in the

context under observation, but is also made aware of the complexity and difficulty in breaking it down in order to analyze and understand it;

- objectified description of actions, put together via a pre-constructed transcription and coding grid and (re)defined according to the theory and the state of the art given (step 2, Figure 6): by its synergetic nature, this second requirement allows participants' observations, knowledge and know-how to be weighed objectively, producing a cross-understanding and a common meaning, combining individual reflections with those of the group;
- the comparison of qualitative / quantitative analyses of the activity (step 3, Figure 6): this requirement ensures complementarity of the data analyzed, thereby facilitating the act of taking a step back;
- jointly highlighting the results (step 4, Figure 6): co-constructing (new) collectively negotiated knowledge aids in the emergence of a shared culture, which firstly concerns the problem defined, studied and questioned by the group; secondly, this concerns the approach that directly or indirectly affects how they act in their own activity and with respect to others. We believe that this type of irreversibility promotes hybridization of the perspective and the dialogue between the worlds of research and practice, often quite distinct from one another in university and/or "professionalizing" courses.

Even though collaborative action research may encounter some resistance, we find this approach to be scientific, albeit one which has unique qualities.

Its first singularity is of an epistemological nature. Indeed, it requires managing a dichotomy between data collection (which can only be achieved by the observers) and an action-research approach, which aims to be collaborative through the involvement of designers in the overall reflection (with these observers) on their design and collaboration activities. To avoid this dichotomy while respecting collaborative action research approaches, the workshop+ proposed puts forth several methodological, theoretical and analytical tools for the joint collection, processing and analysis of data harvested. These tools are defined so that, once the "experimental" phase has ended, all participants work together on the reflection phases. This approach seems to deviate from the classical conceptions of scientific work. Nevertheless, if the approach proposed here is paralleled with a conventional scientific approach, it is possible to show that one approach furthers the other, and that they do not contradict one another (Figure 6).

Its second singularity lies in its flexibility to adapt to the context being studied, i.e., its ability to take into account the specificity of each advanced training into which it is inserted (engineering, architecture, design, ergonomics, etc.). To do so, the protocol proposed enables course modules to be integrated, which provide the necessary theoretical knowledge, contextualized to fit the observed activity. Then, the protocol makes it possible to set the two aspects of the complex collective activity against one another: the process and the content addressed by the group. The focus of the research is as much to do with the specificity of each participant, as their workspace, documents, and interactions with other collaborators. The method of direct observation, without having recourse to recording video data, also serves to streamline the process of taking notes "on the fly." This process is less cumbersome than processing verbalization, but it does not exclusively produce qualitative observations. With COMMON Tools, the researcher also has rapid, easy access to graphs during the analysis phase with a variety of graph styles available, among which (s)he can choose those deemed most appropriate with respect to the research question at hand.

The ability to renew, to question and/or to add criteria and categories during transcription and coding is favoured by the flexibility of this approach, thereby making it possible to:

- analyze a corpus resulting from various configurations of collective activities involving multiple participants;
- leave the researcher free to update his/her grid and thus avoid preconceptions established prior to the activity, without any possibility of challenging them; but in addition,
- prevent the "hardening" of some concepts that might gradually stray from their initial purpose and context.

Within this dynamic position, between theoretical knowledge and practical knowledge, lies the third singularity of our collaborative action-research approach. Before examining this, a difficulty occurring at the data processing step should be highlighted (cf. Section IV.B). This problem concerns the analyst's choice of different criteria when coding for each action to be processed. It is sometimes difficult to categorize every action exclusively and definitively. However, the grid can split proposed actions (vertically, with respect to time) into sub-actions and also offers the analyst the possibility to cross two categories (horizontally encoded) and, therefore, to clearly specify the links between one test and another. This flexibility and crossover must be preserved so as not to place the data solely according to the prior interpretation of the analyst, who may quickly develop shortcuts or overly direct coding according to his or her own preconceptions. Questioning "given theoretical knowledge" thanks to "observed practice", collectively and objectively through a scientific approach, represents the second interest of workshop+, i.e., adopting a collaborative action-research project mirrored against what a scientific approach constitutes.

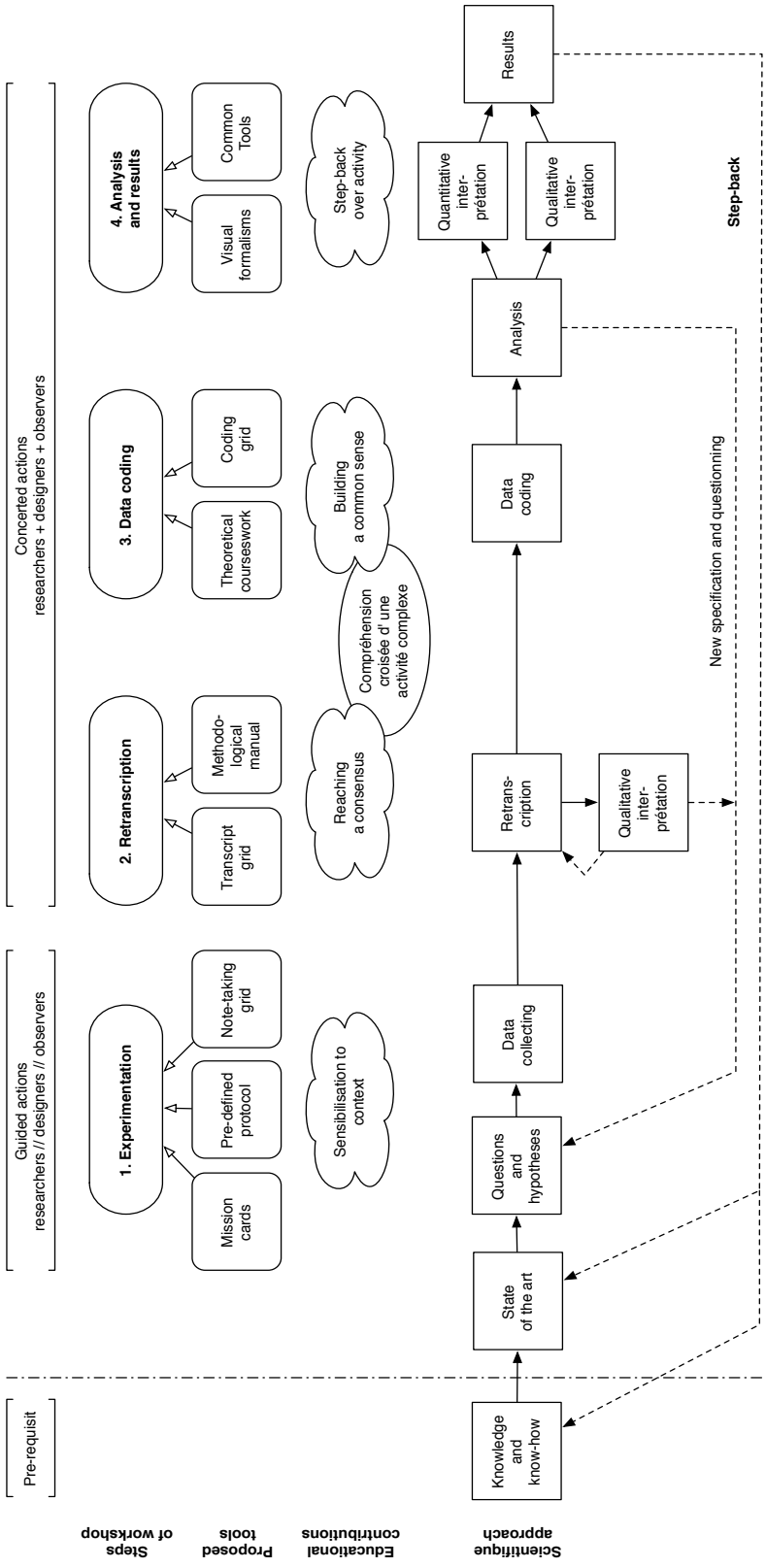


Figure 6. Scientific approach in the workshop+

VIII. INSTRUMENTATION OF TAKING A STEP BACK

In the notion of taking a step back and questioning activity, it is not a matter of tinkering with, adjusting or accommodating methodological, theoretical and analytical tools available to learners (Figure 7). It is more a question of degree of adaptability and taking into account the context studied. Accordingly, 85% of participants stressed the complementarity of support tools available to them in ensuring the establishment of a common reflective space and the construction of this constantly evolving collective intelligence.

The implementation of these tools was defined to address the activity, both qualitatively and quantitatively, promoting continuous distancing and joint interpretation of results highlighted, at every step of the workshop+. Via its predefined criteria, the grid (steps 2 and 3, Figure 4) tends to bring practice closer to experience, observation and analysis. By the quantitative illustration of data laid out according to various chosen criteria, Common Tools lets the user highlight the observed peculiarities of the design and collaboration process. It requires learners to rank the processed data and choose the appropriate visual formalism (step 4, Figure 4). This step encourages them to redefine their objectives and co-construct their research questions, as well as to identify what should be valued and highlighted in their results. The mediation offered by the tool allows them to step back, uncover points of view and shift meaning thanks to rapid access to graph styles helping to objectify and co-construct the interpretation. Over 70% of students highlighted the relevance of such a tool for interpreting data from coding grids. Some learners confirmed even that "perceiving my design and collaborative activity in a different way from this experience generates a step back and an awareness that lead us to question our actions and regulate them." In this way, they capture the complexity, as well as the involvement of the context, of participants' roles, of communication strategies used and of the design process itself in the way they work together.

However, the proliferation of graphs provided by COMMON Tools renders the work of analysis and interpretation of processed data difficult, especially for learners involved for the first time in a scientific approach. Indeed, so as not to make the tool too limiting, it is important to keep this flexibility in the choice of graph as well as in terms of the variety of criteria to represent. Nevertheless, it is contradictory to think that mere statistics alone, automatically performed by a tool, could construct meaning. The method put forward in this article, based on COMMON Tools, serves primarily to build a preliminary quantitative structuring of observations to navigate through the qualitative analysis of a complex collective activity. It does not then claim to attain condensed, definitive interpretations of the activity directly through a set of quantitative data. Subsequent interpretive work is needed, which would allow the researcher/analyst to quantitatively confirm or reject hypotheses proposed during observations and highlighted qualitatively in the corpus addressed.

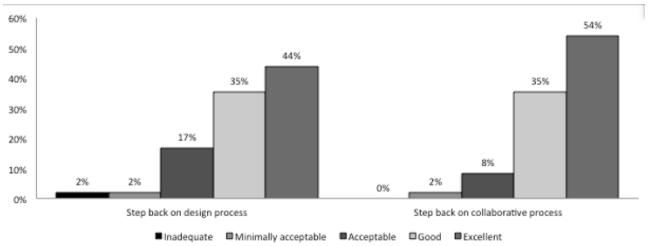


Figure 7. Use of workshop+ in taking a step back from design and collaborative activities

IX. CONCLUSION

What does such a workshop serve to do in an advanced design training course in a professionalizing context? This article seeks to shed light on this very question.

Indeed, comprehending ongoing design processes and providing new insights into collaboration by "doing-and-watching" rather than by simply "doing" (classic workshop approach) or "watching" (classical research approach) are the focuses when implementing collaborative action research. The approach we have chosen to adopt here attempts to bring the world of practice and the world of research. Applied to training during the final year of study in the field of design (i.e., in the Master's or the second year in a Research Master's) or in professional contexts, our goal is to promote the sharing of epistemological and educational space:

- for teachers, this enables them to tailor training on design in order to teach perspective;
- for learners, this offers tools to (1) co-construct a reflection on expertise (designing), (2) structure and enrich their mastery of this expertise, (3) communicate and work on communicating design, and (4) develop a critical mind by confronting points of view so as to start taking a step back, thanks to research practices in design;
- for researchers: it helps to explain the design and collaboration processes in various fields and to apply the approach to advance research in design.

Yet sharing points of view is not sufficient to produce knowledge. That is why this analytical approach introduces multiple (methodological, theoretical and analytical) tools promoting the act of taking a step back and questioning by the objectified co-construction of meaning (between researchers/supervisors, designers and observers) with a view to democratization of knowledge. But to what extent is this type of knowledge likely to be accepted, recognized and/or taken into account, both in the scientific and professional communities?

To promote this acceptance, it is necessary to develop an epistemological framework in line with the scientific requirements and the professional reality in which the collaborative action-research approach is placed. The aim here is to ensure a coherent, ethical and participatory partnership environment, where knowledge acquired from the academic world has no predominance on the knowledge gained from practice. Still, they must not ignore the theoretical production either, mirroring with other models

constructed in advance, or processing in general. The conditions for co-construction of knowledge and meaning must be clarified well in advance.

Therefore, the definition of grids and criteria must be described thoroughly and put forward from theoretical research carried out by peers. The students' feedback shows that these grids help in characterization, precision, confrontation and distinction among different viewpoints. In this way, they participate in the process of objectification, continuous reflection and taking a step back, necessary to comprehend collaborative activity in design. Thus, coding concerted actions and comparing points of view promote deconstruction of know-how by the re-construction and co-construction of knowledge. One limitation of this tool, however, is the time spent transcribing (the result of reaching a consensus among all participants, which can consume a great deal of time). Nevertheless, this investment earns a quick return by the automated processing of data via Common Tools, the second major tool for this process.

The Common Tools web platform supports quantitative and graphical data processing. However, managing and interpreting a substantial number of graphs produced by Common Tools from co-encoded data remains difficult to handle. Over 10,000 potential graphs are provided by experience and little time is available for interpreting them. This complex analysis generally intimidates learners. Therefore, all participants are invited to (1) re-examine the whole issue on "the analysis of a collaborative design activity" by splitting it into co-defined sub-questions, (2) perform a preliminary qualitative, synthetic analysis on the whole activity and, (3) foster awareness of the relevance of a particular visual formalism in answering a particular question and/or promoting a particular hypothesis.

The result of such an approach should not be simplified or seen as the sum of participants' interests or interpretations, but rather as a dialogue co-constructed iteratively and continuously throughout the constituent stages of the workshop+. Moreover, the outcome may not match initial expectations, observations and preconceptions.

As already mentioned, the work of implementing this type of approach is feasible in the framework of a professional setting. What is more, we have participated in its initiation in several specialized architectural and engineering firms. Still, we have been faced with a certain reluctance brought about by several concerns. The first stems from the dreaded "pillage" of participants'/designers' expertise by researchers collaborating with them. The second concern relates to publishing results that are "discussed and, thus, valued far from the field where the data was collected and the first analyses performed" [46, p.28]. Added to this is the fact that publishing and communicating such results to other scientists outside of their own field does not seem to be a priority for practitioners. The real (but nonetheless legitimate) gap between the practitioner's priorities and those of the researcher can be a real barrier in the collaborative action research, especially in that "publishing", for a researcher, is a real need in his or her scientific practice. We believe that this fact should not hamper the application of this type of approach in a professional context, but must, on the contrary, find inspiration in aspects of real experiences. Its appraisal, both among scientific communities and practitioners, will encourage the production of academic knowledge in continuous connection with the reality on the ground: it requires cross-referencing "knowledge in support of know-how" and in return, "know-how in support of knowledge."

It is towards this action, alongside practitioners and in the field, that we aim to follow up this work. More than being merely interventionist, this entails driving and managing change in constant motion, which strives to be well-suited to its context and to all the participants involved in this type of activity.

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