This paper is based on empirical data obtained from two case studies whereby collaborative design of teams composed of four recent graduates with different backgrounds were studied. In both cases, the collected data is related to the interactions of team members toward the development of a design solution in response to a brief. Although the study of the collaborative design process is an essential part of this work, the focus of the paper is on the potential of an expanded Activity Theory as a methodological framework that allows detailed analysis of collaboration. A five-step data processing approach contributed to the emergence of a new theoretical model. The model, an expanded version of Activity Theory, takes into account creative and contextual processes of collaborative design, allowing for thorough data analysis and the production of systemic interpretation of design activity in context. Titled Designerly Activity Theory, we present our reasoning and supporting references as the contribution of this paper having potential to offer a situated framework for the ontology of design research.

design team; activity theory; collaborative design; design research

1 Introduction
In projects involving design thinking, it is very common that researchers collect data from dialogues between designers and clients. These conversations occur between designers as teams involving other designers or professionals from various disciplines. In these instances, transcripts form the main document for data analysis. Transcripts are produced, coded and analysed with different criteria and in different ways. For example, we refer to the works of Cross and Cross (1995), Valkenburg and Dorst (1998), Valkenburg (2000), Dong (2005), Oak (2011), McDonnell (2016) and many others, where various frameworks are used for reasoning, evaluating, understanding, discovering and bringing new insights to the design community. In sum, as mentioned by Matthews & Heinemann (2012, p. 649): “Since the ‘empirical turn’ in design studies, many methods drawn from the social and human sciences have been applied to the study of designers’ activities.”
Looking closer at collaborative design, we examined Activity Theory as an alternative basis on which data from transcripts can be meaningfully and consistently understood. More precisely, we ask ourselves the following question: Can Activity Theory framework offer an underlying structure for coding and data analysis, and help us to better understand interactions and contradictions between team members as well as the design process of multi-disciplinary teams? This article proposes to build on the acknowledged research framework of Activity Theory to test its application and propose a theoretical expansion emerging from our empirical data analysis.

Due to the early stage of this research project, the present article only focuses on the research methodology, more precisely, to find an answer to the above question. The promising Designerly Activity Theory that is discussed later in this paper is going to be used, in a near future, as a framework to analyse and interpret data of five case studies that share a unique controlled condition. Those case studies will focus on the design process of collaborating teams to enrich the knowledge surrounding team-related dynamics and team contradictions—which is a strong feature of Activity Theory. Ultimately, we seek that the proposed model, will allow for deep data analysis and the production of in-depth and systemic interpretation of design activities. The model emerged from the data retrieved from two case studies, and after many cycles of data coding, trial and error, and hours of negotiations. The micro-analysis of these empirical observations, with the help of Activity Theory, guided us towards the development of a situated methodological approach, which we value for its potential, reliability and validity. The structure of the article will follow Leplat’s most characteristic phases of scientific research: data gathering, data processing and generalization, including comparing conclusions with existing knowledge (Leplat, 2002). Before detailing these phases of our research project, we will introduce the purpose and initial theoretical framework of our study.

2 Purpose of the study and planning

Before providing other details, we would like to specify that our research project is guided by two leading objectives. The first, being the main focus of this article, is to elaborate an innovative methodological approach based on Activity Theory. At the same time, we wish to contribute to the refinement of design research methods. Two case studies out of five constitute the context for this objective. The second objective is to develop and communicate our understanding of the interactions and processes put in practice by interdisciplinary teams. This objective is not represented in this article, but will culminate in future contributions that will delve into this challenge. Although our search for the refinement of knowledge on collaborative design is continuous in our research project, the remaining of this article will strictly focus on the methodological features of the expanded activity theory framework we seek to present.

In order to plan a coherent research program, we conducted a total of five case studies, which will be introduced later. Each case study combined the expertise of a multidisciplinary team of graduates. The first case study has been analyzed and discussed in a previous article (Zahedi, Tessier & Hawey, 2017). The methodological approach that we present here is built on the enriched understanding of the first case study and the analysis of a second case study.

3 Activity Theory

Activity Theory (AT) is a theoretical framework based on the works of Lev Vygotsky, Alexei Leont’ev and others. AT was developed further and adapted to our complex collective reality by Yrjö Engeström. The theory uses the systemic investigation of contradictions to solve problematic situations. AT is used in concordance with a triangular model composed of seven interacting components (Figure 1): subject, object, tools, rules, community, division of labor and outcome.
A number of reasons motivate us to explore AT and suggest it as a promising framework for research on collaborative design. First of all, activity theoretical research explores collaborative systems, including all related members of the community, actors and stakeholders (Engeström, 2001). Adopting a ‘multi-voiced’ perspective is particularly relevant to context-based and user-centered design projects. Secondly, the theory sees contradictions in a system as drivers for change and development (Engeström, Miettinen, & Punamäki, 1999). Contradictions are difficult to perceive, but “manifest themselves through disturbances, ruptures and small unremarkable innovations” (Engeström, 1999, p. 68). Finally, AT adopts a systemic vision that seeks to find pertinent solutions that are also adapted to neighbouring systems. In short, multi-voiced perspective, contradictions allowing changes, and systemic vision are crucial when designing collaboratively.

3.1 Why Activity Theory?
For more than two decades now, Activity Theory is being recognized as an effective tool to frame the design process by organizing opinions and needs of all stakeholders involved. As mentioned by Nardi (1996), AT is a means of studying practice: it is object-oriented and can be used for designing of human-computer interactions. Heaton (1998) comments that AT “offers a framework for describing how changes in consciousness are directly related to the material and social conditions” and “provide a shared vocabulary for designers”.

Still, we note an important difference between the most common way to use AT to frame design projects, and what we are seeking with the present contribution. We consider that the theory has strong potential to be used as a powerful framework to decrypt and interpret the design activity of a team within an activity system. The theory is a powerful approach “to analyse development within practice through the social and contextual activities in which people develop their skills, personalities and consciousness” (Chatzakis et al., 2016, p. 1893 referring to Sannino et al., 2009). It is with this systemic and contextualized perspective of the model that its strong correspondence with design activity becomes clear.

Activity Theory provides a simple but strong visual model that allows for general understanding and interpretation of a situation and its evolution in time (Chatzakis et al., 2016, p. 1893). Also, as mentioned by Engeström, Miettinen and Punamäki in Perspectives on Activity Theory (1999), we see AT as fit for today’s complex and open-ended challenges: “Activity theory should not be regarded as a narrowly psychological theory but rather as a broad approach that takes a new perspective on and develops novel conceptual tools for tackling many of the theoretical and methodological questions that cut across the social sciences today” (Engeström et al. 1999, p. 8).

4 Case studies and data gathering
The phase of data gathering was executed through the completion of five case studies. According to Creswell, “a case study is an in-depth exploration of a bounded system based on extensive data collection” (Creswell, 2012, p. 464). The author specifies that bounded signifies isolated in time and place for in-depth observations. More specifically, we opted for researcher-provoked data, as this type of data is created in controlled setting for all cases and considered reliable (Silverman, 2006). The case studies proposed to team up four graduate students from different disciplines: for example, one designer, one engineer, one marketer and one student from a social science field –
both male and female. Teams met on one occasion for 2.5 hours. They had access to a ‘live’ environment (CollaborationLab) allowing for easy collaboration and the use of different materials (computers, whiteboard, sketching material). Inspired from Dorst and Cross’ 2001 article Creativity in the design process: co-evolution of problem-solution, teams were asked to design a litter-disposal system for trains. Each team had to provide a realistic solution and respond to the deliverables: sketch of form and function, dimensions, materials, cost estimate. Available to them were documents such as technical plans of the train, client’s design criteria and other contextual information. Participants could at any time ask questions to the researchers or use the Internet to gather information.

The case studies were recorded with audio and video materials and participants were asked to think aloud. According to Someren et al. (1994, p. 1), the think aloud protocol “is a very direct method to gain insight in the knowledge and methods of human problem-solving”. It allows to connect the participant’s actions with a “concurrent verbal report of what they are thinking” (Valkenburg, 2000, p. 85). Three non-participant researchers observed the teams’ actions and were each asked to take objective notes on one aspect: use of tools, verbal interactions or team dynamics.

5 Data Processing – Global methodological approach

Our exploratory approach combining the context of collaborative design projects and the AT framework was developed in four subsequent stages. Stage 1 sought to demonstrate the use of the theory and communicate its potential to the design community. To do so, the first case study was coded and analyzed. Stage 2 was guided by the need for more validity and reliability. It sought to extend and confirm the first results in a second case study. Stage 3 pursued the objective of developing a more precise and reliable methodological and analytical approach, specific to the study of collaborative design. Finally, Stage 4 is ongoing and seeks to identify emerging patterns from the data across the five case studies completed to this date. Each stage will be detailed in the remaining of the present section.

Inspired from Engeström’s fundamental question “How does one do concrete research on the basis of Activity Theory?” (Engeström, 1993,p. 65), our research project is guided by this overarching question: How does one do concrete research ‘on the collective activity of a design team’ on the basis of Activity Theory? Each stage seeks to answer a specific question breaking this major inquiry into smaller achievements.

5.1 Stage 1: Demonstration of the use of AT

The first stage of our methodological exploration was developed around a first case study (Team A). It was centered on the exploration of the following question: Can AT be used to support the analysis of collaborative design? If so, how can it be implemented? As this question anticipated preliminary findings, we set our objective to be the demonstration of AT as a complementary analytical tool for the design research community.

In order to answer our research question and respond to this first objective, we developed an approach for analyzing qualitative data, obtained from talk amongst design team. The data processing is composed of five steps:

1. Verbatim transcription
2. Transcription coding
3. Identification of episodes and related main contradictions
4. Interpretation of each episode and its related contradiction into AT models
5. Representation of AT models on a timeline

Step 1 consists in the verbatim transcription of all interactions from the recorded material. Team A’s transcription is composed of 1073 lines in total, which corresponds to the equal amount of exchanges between members of the design team.
Step 2 involves the coding of more or less every turn of talk according to one or more component of the activity triangle (i.e.: subject, object, tools, rules, community, division of labor or outcome). Figure 2 shows an example of the typical grid that was used during the coding. In order to allow for greater validity and reliability, the data was coded individually by two researchers (Ph.D. students). A third researcher was solicited later on to guide the arbitration of the two coded files. This intervention was for those lines of talks where the two first researchers had different coding.

<table>
<thead>
<tr>
<th>Time</th>
<th>Transcription</th>
<th>Subject</th>
<th>Tools</th>
<th>Object</th>
<th>Rules</th>
<th>Community</th>
<th>Div of Labor</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:31:54</td>
<td>[H3] Mais là, il faudrait passer à nos besoins. Quoi ci.</td>
<td>[F1] Mais pour moi, il faut nos besoins!</td>
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<td></td>
<td>[H3] Bon, déterminer les besoins.</td>
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<tr>
<td></td>
<td>[F1] Coon, j'ai pris toute la place sur le tableau... On va le faire sur la... Est-ce qu'il y a d'autres couleurs?</td>
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<tr>
<td></td>
<td>[H3] Je vais prendre en photo et l'afficher ensuite</td>
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<td></td>
<td>[F1] Ah bin on va le garder je pense.</td>
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<tr>
<td></td>
<td>[H1] Fac là c'est déterminer les besoins?</td>
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<tr>
<td></td>
<td>[F1] Oui! Alors les acteurs impliqués la-dedans...</td>
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<tr>
<td></td>
<td>[H2] Ceux qui conviennent.</td>
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<tr>
<td></td>
<td>[F1] On est secondaires.</td>
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</tr>
<tr>
<td></td>
<td>[F1] Tiens, il y a des gens, en fait les usagers.</td>
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</tr>
<tr>
<td></td>
<td>[H1] Très important.</td>
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</tr>
<tr>
<td></td>
<td>[F1] Après ça, il y a ceux qui vont dire si ça passe au conseil ou pas, alors Via Rail. Ou on met juste les employés de ménage ?</td>
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</tr>
</tbody>
</table>

Figure 2 Coding grid with component from activity triangle
Black code represents assertive talks, whereas grey code represents secondary components.

Data coding allowed the emergence of distinct clusters of components that seemed more solicited during certain stages of the case study. Therefore, Step 3 of the data processing served for the identification of episodes and their related main contradictions. Episodes refer to distinct stages of the development of the collaborative design project and are associated to specific discussions and negotiations on a more focused theme. In the first case study, 7 episodes were identified. As shown in Table 1, these episodes create a unique sequence of 19 occurrences.

| Team A | 1 | 3 | 1 | 2 | 3 | 5 | 2 | 4 | 5 | 1 | 4/4/4 | 5 | 4 | 5 | 4 | 6 | 7 |

Step 4 combined the use of talk analysis and of the data coding. Linking together these two data interpretations led us to depict the main contradiction of the episode into an AT model. In order to do so, we analyzed the dominating clusters of components and concentrated on common attributes of the participant’s discourses. We adopted Oak’s viewpoint “by focusing on the everyday, taken-for-granted features of talk within the settings of design practice, we can see how participants in practice achieve the comprehension and negotiation that allow designed objects to be constructed as both personally and socially meaningful” (Oak, 2010, p. 211).

Step 5 concerns the representation of these depicted episodes in a visual analysis tool organized as a timeline (Figure 3). The timeline provides quick visual reference on the evolution of the project, movements of the main contradictions and team-specific dynamics.

Figure 3 Team A’s timeline with activity triangles
The timeline description is as follows: Approximately, the first half-hour (Episode [1]) was a period for expressing team’s way of tackling the project. During the next half-hour (Episode [2]), the team showed a strong interest in developing management tools (schedule, tasks listing, etc.). Then, in Episode [3], participants concentrated on the identification of users and stakeholders to consider for developing their concept. Between hours 1:00 and 2:00, corresponding to Episodes [4] and [5], the participants discussed the clients demands and project regulations and translated their decisions into criteria for the final product. We address these episodes simultaneously because the participants alternated from one to the other. During Episode [6], they divided the workload strategically in-between the participants according to their expertise (based on the transcript, this division was for efficiency concerns). Finally, Episode [7] consisted of a recap of the client’s requests, project objectives and design criteria.

Representation of the episodes on the timeline granted for a consistent description and interpretation of the team in-context. Compared to the timeline, more episodes are shown on Table 1. In fact, only episodes that happened in a chunk of significant time (more than 15-20 minutes) are shown on the timeline. Results and findings from this first case study were reported in a paper presented at a conference and later published in a scientific journal (Zahedi et al., 2017).

Strong similarities between our findings and important scientific publications allow us to answer positively to our first research question stated earlier. We relied on findings from many design thinkers who have highlighted the iterative aspect of the design process (Nelson & Stolterman, 2003; Schöön, 1983; Valkenburg, 2000) and, particularly, on Dorst and Cross’ article on co-evolution of problem-solution spaces (2001) to validate the iterative loops identified (see recurring episodes [4] and [5] in Table 1). In addition, the observed dynamics bring to light Vygotsky’s zone of proximal development (1978) to account for collaborative learning. In conclusion of this first research stage, we argue that AT can be used for the sustained analysis of collaborative design and should be explored further by design researchers in order to help them discover its potential.

5.2 Stage 2: Validity and reliability

The second stage involved a second case study (Team B) and focused on the same question as Stage 1. Additionally, we sought to answer a new research question: Can the results of the first case study be extended and confirmed with the analysis of a second case study? We wanted to confirm the validity and reliability of the implementation of AT in a collaborative design context. Overall, the second stage was led by the ambition to generalize our findings to show, eventually, a greater legitimacy of our results.

To do so, we used the same methodological process introduced in the first stage. The same five data processing steps were completed on Team B and led to similar findings as in Team A. We were able to identify the same episodes in a similar sequence for both teams. However, we observed different timeframes (see Figure 4) and different sequences for smaller chunk of time (see Table 2).

<table>
<thead>
<tr>
<th>Table 2 Team B’s episode sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team B</td>
</tr>
</tbody>
</table>

![Figure 4 Team B’s timeline with activity triangles](image)

The identification of similar episodes in the two case studies encouraged us to define more precisely their nature. Table 3 presents the definition and outcome of each episode.

<table>
<thead>
<tr>
<th>Table 3 Episode definitions and outcomes. Based on co-reflective practice model (Zahedi &amp; Heaton, 2017).</th>
</tr>
</thead>
</table>

325
<table>
<thead>
<tr>
<th>Episode ID</th>
<th>Definition</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1]</td>
<td>Episode expresses the team’s way of tackling the project. Corresponds to the “fuzzy front end”.</td>
<td>Gain a better understanding of the project brief.</td>
</tr>
<tr>
<td>[2]</td>
<td>Episode of “constraining” by the development of management tools such as schedules, tasks and objective listings.</td>
<td>Gain a general sense of the work session’s flow.</td>
</tr>
<tr>
<td>[3]</td>
<td>Identification of potential users, project stakeholders and needs through “naming”.</td>
<td>Gain a team’s shared vision of the future design. Foster shared understanding.</td>
</tr>
<tr>
<td>[4]</td>
<td>Discuss the design options, stimulate ideation, “framing” according to specific themes or aspects.</td>
<td>Gain inspiration and stimulate ideas. Foster knowledge co-creation.</td>
</tr>
<tr>
<td>[5]</td>
<td>Episode of collective “deciding” through the creation of new design criteria. Gives a clear direction to the design development.</td>
<td>Agree on collective decisions to use in the design. Bring new questions for discussion - back to [4].</td>
</tr>
<tr>
<td>[6]</td>
<td>Strategic workload division according to participants’ expertise, skills and knowledge.</td>
<td>Gain strategic efficiency for the project’s development.</td>
</tr>
<tr>
<td>[7]</td>
<td>Recap of the client’s requests, project objectives and design criteria to validate the final design.</td>
<td>Agreement that all aspects of the project and deliverables have been covered. Refine the outcome.</td>
</tr>
</tbody>
</table>

So far, the answer to our research inquiries is also positive. Highly consistent results emerged from the coding and analysis of the two teams. We link our findings to those of Langan-Fox (2004 cited in Kleinsmann, 2006) who developed a model for describing shared understanding of a team. The model is based on the following phases: (1) team’s formation and initial developments, (2) development of team’s understanding about causal relationships, and (3) team’s high level performance as team members are more accustomed to each other. Thus, Langan-Fox et al. (2004) call this finding a team mental model in three phases. We see similarities between our seven episodes and these three, less detailed, phases. We can link phase 1 to Episodes [1] and [2], phase 2 to [3], [4] and [5] and phase 3 to [6] and [7]. What is more, by comparing the results of both case studies and by drawing preliminary conclusions from our experience, we felt a need to refine our coding, which led to the exploratory stage 3.

5.3 Stage 3: Development of the methodological and analytical approach

The third stage of our methodological process was initiated by an insight on the nature of tools in relation to the observed design process. Through multiple codings and readings of the transcriptions, coders involved in the processing had noted that participants tended to work with different types of tools. At some point, a participant was using ‘material tools’, such as a pencil for sketching or a computer for searching information. In other instances, the same participant could use ‘tools for thinking’ when asking questions or drawing attention to encourage ideation and exploration. In relation to this possible distribution of the tools component we asked ourselves the following research question: Can AT be refined in order to fit a more precise and detailed analysis of collaborative design? In answering this question we sought to refine the coding and allow the emergence of new interpretations. Moreover, we also sought to test the pertinence of a second dimension specific to collaborative design reasoning in the activity triangle. Through the exploration of the coding of both teams and of each researcher’s notes, we identified four initial components that could potentially be distributed on two complementary dimensions. The first dimension is the original activity triangle, while the second dimension would be associated to designerly thinking and behaviors (Cross, 2001, 2006; Cross, Christiaans, & Dorst, 1997). Through rigorous recoding of Team A’s case study new clarity emerged from the data. The first four
components identified are the following (justifications and related references will be introduced in the next section):

- Tools distributed with *signs*
- Rules distributed with *design criteria*
- Division of labor distributed with *process*
- Object distributed with *object in context*

To confirm the potential of this new dimension, Team B was also recoded with these new components in mind. A new researcher was teamed with an already involved researcher to recode the data and provide a fresher viewpoint on Team B’s dynamics. They were asked to code the transcription using a new grid integrating the distributed components mentioned above. Their codings were revised by a more experienced researcher and challenged when necessary. This comparison of coding results allowed for greater inner validity and resulted in the adoption of one shared coding grid. During this revision process, the distribution of the two other components became clearer:

- Subject distributed with *collective subject*
- Community distributed with *imagined community*

<table>
<thead>
<tr>
<th>Time</th>
<th>Transcription</th>
<th>Subject</th>
<th>Collective subject</th>
<th>Tools</th>
<th>Signs</th>
<th>Object</th>
<th>Object in context</th>
<th>Rules</th>
<th>Design criteria</th>
<th>Comm</th>
<th>Imagined community</th>
<th>Div of labor</th>
<th>Process</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:46</td>
<td>(H2) Alors, ça pourrait être... Vous n’avez pas de problème de truc, ça pourrait être juste un gliss, pas un vrai vrai. Vous avez une idée de quoi ça va comme un peu souiller un peu la chose.</td>
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<td>01:03</td>
<td>(H2) Faut regarder un peu qu’elles co qui se fait.</td>
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<tr>
<td>01:15</td>
<td>(H2) Juste faire quelque chose qui soit équitable pour le p’tit qui les sœurs sortent.</td>
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<tr>
<td>01:36</td>
<td>(H1) Mais à la fin, il faudra parler, si c’est comme quelque chose qui lève la sous de même.</td>
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<td>01:42</td>
<td>(H3) Ouais.</td>
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<tr>
<td>01:43</td>
<td>(H1) Mais si tu ouvres quelque chose comme ça, tu peux pas.</td>
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<tr>
<td>01:46</td>
<td>(H2) Le papier à mon avis a pas besoin de... Du moment que ça ne vous pas tant frustrés.</td>
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<tr>
<td>02:00</td>
<td>(H1) Moi je pense que c’est quelque chose qui s’ouvre, comme une même.</td>
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<tr>
<td>02:08</td>
<td>(H1) Mais ça croule pour l’usager ou ça ouvre pour le garde de ménage ?</td>
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<tr>
<td>02:12</td>
<td>(H0) Moi aussi.</td>
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<tr>
<td>02:15</td>
<td>(H2) Ah ou.</td>
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<td>02:16</td>
<td>(H2) Parce que tout d’abord, c’est des poubelles à Mérinhey dans le métier, tu gagnes les touts de plus.</td>
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<td>02:20</td>
<td>(H2) Il a ouvert pas pour l’usager, il faut que ce soit un truc.</td>
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*Figure 5 Complete grid with expanded designerly triangle components*

Once again, both transcripts were recoded in order to test and confirm the applicability of these new components. This time, we were testing the complete expanded version of the *designerly activity triangle* (Figure 5). Building on this refined version, we applied the same processing steps described before: identification of episodes, identification of contradictions and timeline representation. Overall, we achieved similar episode divisions in both teams, but the timelines revealed interesting information specific to both teams (Figures 6 and 7).

*Figure 6 Team A’s timeline with expanded triangle*
Figures 6 and 7 illustrate that while both teams have achieved in their own way to propose a realistic solution to the design problem, they adopted two different pathways and work pace. Our answer to our third research question was also positive: the coding led to a more refined interpretation of the actions and dynamics of both teams.

Using an iterative methodology, our article Understanding Collaborative Design Through Activity Theory (Zahedi et al., 2017) attests that by using the activity triangle and by focusing our attention on the global contradictions emerging from the team’s dynamics we could reach interesting results. We were able to describe the evolution of a team’s co-constructed understanding and follow in detail the development of a design project despite the many back and forth, negotiations and decision-making. This process led to the emergence of the Expanded Activity Theory. In the next section, we will present and argument the proposed designerly activity triangle. By using references to authors and published scientific works, we will attempt to offer thorough justifications for each component of the expanded activity triangle that we call Designerly Activity Theory.

### 6 Generalization – Discussion

Design projects are motivated by innovative discoveries, explorations and unexpected surprises (Dorst & Cross, 2001; Schön, 1983). Similarly, Engeström introduced the concept of transformative agency, which “may be defined as breaking away from the given frame of action and taking initiative to transform it” (Engeström, 2015, p. xxiii). The second dimension that emerged from our data coding is motivated by this transformative agency—unique to design reasoning. In order to gain greater knowledge on these dynamics, exclusive to ill-defined problems, we feel that the addition of a second dimension to the activity triangle is of notable support. We will introduce and justify each pair of components forming the expanded triangle (Figure 8), by starting by the three upper components (subject, object and tools), and conclude with the three social mediators (rules, community and division of labor).
6.1 Subject and Collective subject

As in the initial activity triangle, the subject refers to an individual or team of individuals involved in the activity system. Subject interventions are associated to expert knowledge, disciplinary vocabulary and personal experiences and interests. Design being a social process (Bucciarelli, 1988; Cross & Cross, 1995; Valkenburg & Dorst, 1998), the subject—as a team—goes through many types of communications (i.e. discussions, negotiations, demonstrations, reasoning) and constructs a shared understanding or team mental model. Doing so, the subject develops collective meaning and moves to being a collective subject. Also, we associate the subject component to Bucciarelli’s object-worlds (Bucciarelli, 1988, 2002). In multidisciplinary projects, participants evolve according to their object-worlds—their sets of disciplinary rules. As explained by Kleinsmann, “an object-world contains individual beliefs, interests, knowledge and experiences of an actor, as well as the methods and techniques he is able to use” (Kleinsmann, 2006, p. 44).

The collective subject seeks to clarify the existing interpretative gap between the participants’ object-worlds. It refers to the co-construction of a team’s mental model. Collective subject can only be found in activities that engage two or more participants, since it is explicitly a team dynamic. In collective interactions, we see team members working together towards a shared understanding. In design, shared understanding has been explored by many authors including Kleinsmann, Valkenburg and Buijs (2007, p. 61). They defined the concept as “a similarity in the individual perceptions of actors about either how the design content is conceptualized (content) or how the transactive memory system works (process)”.

6.2 Object and Object in context

The distribution of object and object in context is closely linked to Engeström’s distinction between the generalized and specific subject. The generalized object is socio-culturally embedded in the historical evolution of a system. On the other hand, the specific object “appears to a particular subject, at a given moment, in a given action” (Engeström & Sannino, 2010, p. 6). The main distinction between the two types of object is the social versus individual sense making process. It is possible that a community shares a general object, but each member also has its own specific understanding of the object. In any case, the object can be either material or conceptual (Jonassen & Rohrer-Murphy, 1999, p. 65). In design, although an object can exist by itself, it finds significant value in its purpose and in the context of use (Krippendorff, 2008).

In summary, the object component—as part of the initial activity triangle—allows for an individual perspective of the specific object, while the object in context—part of the second dimension—allows for a collective understanding of the generalized object. While the team seeks for the same objective, they foster their shared understanding, but during the entire process, each participant is also embedded in each of their own inquiries due to their different perspectives and individual knowledge.

6.3 Tools and Signs

Along with more traditional physical tools, conversations—as tools of collaborative design—are studied by design researchers (i.e. Cross and Cross, 1995; Dong, 2005; Oak, 2010; McDonnell, 2016; Zahedi et al., 2016). Others have studied boundary objects (Leigh Star, 1954–2010), which are considered as tools to help us understand how team members work together. Literature also contains many other categorizations of tools. However, by focusing on the tools component of the activity triangle we notice that it is equally referred to as instruments and artefacts. Wartofsky (1979) distinguished three types of artefacts: primary, secondary, and tertiary. Still, so far, all three types are gathered under the Tools component of the AT model. Our data made it visible that, in collaborative design, there is a distinction between material tools and talks that make team members reflect in a different way.

According to Kuutti (1996, p. 28), “a ‘tool’ can be anything which is used in the transformation process, including both material tools and tools for thinking”. Based on this premise, we explored Vygotsky’s distinction between the concepts of tools and signs. For Vygotsky, tools and signs always
mediate human interactions with their environment. Tools and signs have intrinsically different mediated functions (Vygotsky, 1978). Tools assist human behaviour, just like a stick helps an individual in reaching something, and signs are cultural productions created according to the time and place under an individual’s influence. The following quote explains clearly the difference between the two:

*The tool’s function is to serve as the conductor of human influence on the object of activity; it is externally oriented; it must lead to a change in objects [...] The sign, on the other hand, changes nothing in the object of a psychological operation. It is a means of internal activity aimed at mastering oneself; the sign is internally oriented.* (Vygotsky, 1978, p. 55)

In a design project, the *tools* are material: they can take the form of pencils, whiteboards, computers, sketching materials, prototypes, etc. They allow externalizing ideas, fostering understanding between participants and achieving concrete operations (Engeström, 2015). In design, material tools are seen as “a form of thinking with their hands that allows [designers] to experience the perceptual, emotional, and aesthetic feel of the building [or artefact] as they are thinking their way through the designing of it” (Boland et al., 2008, p. 19). On the other hand, signs are self-mediated and associated to the expertise and experiences of participants. Through the use of signs, participants generate ideas and propositions unique to what they know, understand and imagine in the current context of a design project. Engeström states that “only psychological tools imply and require reflective mediation” (Engeström, 2015, p. 48). Additionally, both tools and signs support the designer in the construction of his mental model. As Kolko puts it, “the externalization of the research data allows for a progressive escape from the mess of content that has been gathered” (Kolko, 2010, p. 19).

This differentiation between tools and signs is closely related to the internalization and externalization process. While the participants integrate new knowledge from others and from the situation, they produce new concepts as they evolve in the system. These learning dynamics are labelled as ‘internalization’ and ‘externalization’ (Engeström, 2010). Internalization refers to Vygotsky’s knowledge acquisition process. It is a form of individual appropriation or integration of concepts and ideas supported by social interactions with others. Externalization corresponds to the creative effort for collaborative solutions and “discrete individual innovations” (Engeström, 1999, p. 33). Externalization is linked to the solution-space of fuzzy or ill-defined projects. It asks for team members to generate ideas and to have an integrated understanding and shared vision of the problem. To quote Kolko (2010, p. 18) on externalization: “Once externalized, the ideas become “real”—they become something that can be discussed, defined, embraced, or rejected by any number of people, and the ideas become part of a larger process of synthesis”.

### 6.4 Rules and Design criteria

The distinction between *rules* and *design criteria* lies behind the team’s external and internal constrains. *Rules* are closely linked to Krippendorff’s statement that “objects are always seen in a context (of other things, situations, and users, including the observing self)” (Krippendorff, 1989, p. 12). The *rules* as presented here come from the project’s exterior boundaries—context—and are interpreted as guiding directives. These directives are given to the designers as part of the project brief or regulations associated to the design situation—time, place, etc. For example, *rules* can be related to restrictions in regards to ethics, technology or politics, such national laws or norms. They exist before the entry of the designers in the project and designers have either to navigate around them or challenge them.

Rosson and Carroll argued that “designers need constraints” (Rosson & Carroll, 2002, p. 4). Constraints or *design criteria* contribute to the framing of a design project: it is its “semantic perspective” (Kolko, 2010, p. 23). They are collaborative decisions emerging within the team allowing the project to take form. Frank Gehry said that “constraints are what make a design problem unique and worthy of their best efforts” (Boland et al., 2008, p. 21). Project perspectives
are researched, analysed and reviewed by the designers in order to reconsider the initial problem or question. This exploration leads to the iterative reframing of the project. According to Schön, framing is a sense-making activity based on previous experiences and occurs through the process of reflection-in-action (1994). Frames are understood as tentative ways of regarding a problem combining “a few salient features and relations from what would otherwise be an overwhelmingly complex reality” (Takeda et al., 1999 cited in Kolko, 2010, p. 22; Bucciarelli, 1988; Dorst, 2015). Design criteria contribute to the progressive settlement and refinement of the project frame. At best, in collaborative settings, frames lead to shared understanding among the participants and allow common ground for discussions.

6.5 Community and Imagined community

In the past decades, designers have attributed increasing importance to the end users. As discussed by Kuutti, user-centered approaches can be either active or passive. Some approaches tend to actively include potential users as “full partners” in the design process while others “treat users just as passive objects of ‘requirements elicitation’” (Kuutti, 2009, p. 67). The distribution between the community and the imagined community stands on the differences between these two approaches to the designer’s sense-making. Still, both components refer to “an action-oriented process that people automatically go through in order to integrate experiences into their understanding of the world around them” (Kolko, 2010, p. 18).

Our data analysis allowed the identification of the community component in real, verified information, such as ethnography, but also statistics, interviews, surveys or test bench experiments. In these instances, verified data deals with the habits, needs and behaviours of future users emerging from empirical research. Moreover, stakeholders have come to have an important place in the community as they offer another type of tangible knowledge. Stakeholders are reliable sources since they are often specialists in a certain area of the project. As stated by Krippendorff, the inclusion of stakeholders, as collaborators and opponents, has changed the design process from a “social process that relies on stakeholders with different and potentially conflicting interests” (Krippendorff, 2008, p. 65). In brief, community is an amalgam of knowledgeable sources of information and data feeding the design decisions. However, often due to efficiency, time or money concerns or to allow for more creative opportunities, designers also rely on imagined communities. This component is inspired from Krippendorff’s concept of object context, which he says is “cognitively constructed, whether recognized, anticipated, or wholly imaginary” (Krippendorff, 1989, p. 12). We note that imagined communities emerge from past experiences, interpretations and deductions through which designers conceptualize the potential use of the artefact to be designed—“how users might or should be using an artefact” (Krippendorff, 2008, p. 134).

We observed the use of scenarios, personas and other human-centered approaches in our case studies. As Krippendorff’s puts it, designers consider “maps of possibilities” (Krippendorff, 2008, p. 134). These creative methods are used to provide alternative opportunities to keep the designers moving and reflecting. Some compare the efficiency of sketches to communicate physical features to the efficiency of user scenarios to rapidly depict the core of a situation (Rosson & Carroll, 2002). Scenarios are popular in design projects as they create a common ground for discussion (Krippendorff, 2008), are low-tech, quick to use and easily accessible. They often evoke empathy for the users, raise questions and stimulate reflection. According to Rosson and Carroll, scenarios are detailed propositions “that a designer can evaluate and refine, but it is also rough, so that it can be easily altered, and many details can be deferred” (Rosson & Carroll, 2002, p. 4). Such methods bring those that are not around the table into the solution-search process by sharing possible experience with them.

6.6 Division of labor and Process

The last component is distributed between division of labor and process. The first refers to the separation of tasks according to expertise and skills. It was noted that such division of labor tended to happen towards the end of the case studies—more precisely during episode [6]—because, as observed by Langan-Fox et al. (2004), team members are more comfortable with one another and
understand themselves better. We interpreted this division of labor as a transition from close collaboration to cooperation between the team members. Consequently, we feel appropriate to refer to Peng’s definition of cooperation according to which “participants of different technical specializations communicate and co-ordinate with each other to achieve, or to cope with, design unity in final products” (Peng, 1994, p. 21).

The process component considers ‘design’ in its verb form (Boland et al., 2008), inviting to a series of design actions. Kleinsmann’s definition of collaborative design includes both to achieve agreement on the outcome of the project, as well as the team’s design process (Kleinsmann, 2006). Therefore, Process identifies the adoption of a “design attitude” centered on the open search for potential solutions and new ideas (Boland et al., 2008, p. 13). Such an attitude is closely related to project framing, as introduced earlier. In this instance, we regard framing in its iterative development. Schön proposed that framing is the result of a reflexive process occurring in action (Schön, 1983). Formed of subsequent cycles of refinement, framing contributes to the definition of the problem and solution. Framing contributes to the settlement of ill-defined problems by using abduction as a cognitive process. According to Cross, abduction is the only cognitive process that allows the creation of new knowledge (Cross, 2006). Dorst explains abduction as “how to think from consequences back to causes and working principles” (Dorst, 2015, p. 24) and Kolko cites Roger Martin explaining that abduction is the “logic of what might be” (Kolko, 2010, p. 20). The design attitude, framing and abduction are bounded together for the search of creative opportunities and iterative problem-solving.

7 Conclusion
The present paper focused on the methodological approach that emerged from using Activity Theory as a framework to analyze collaborative design. Following a designerly research practice, we allowed for unpredicted connections to emerge, which lead to the progressive construction of a second dimension to the activity triangle. This exploratory investigation leads us to believe that we have some elements of answer to the research questions of this study. Activity Theory, as a framework, can offer a concrete and solid basis for understanding the collective activity of the design teams. Ultimately, we seek to propose a new ontology for design research allowing us to meaningfully report the fundamental characteristics of a multidisciplinary team’s journey to framing, proposing ideas and decision-making in a design project.

Looking more closely at the evolution of both teams led to the observation of recurring data patterns. These patterns are the focus of Stage 4 (still ongoing), which will result in the publication of another article to answer this last research question: What recurring patterns emerge from the data coded with the expanded activity triangle? Answering this question will lead us to verify the emerging patterns and findings across a total of five case studies. It will also allow us to refine our methodological approach and validate the Designerly Activity Theory. The expanded model will maybe allow identifying successful collaborative patterns in a more objective manner. Finally, we will be able to contrast and compare the five design situations using our Designerly Activity Theory to, potentially, refine our knowledge on collaborative design.

Acknowledgements: We would like to thank the participants of the case studies mentioned in this article who fully participated in the design activity and gave us the opportunity to observe them. We are grateful to our research assistants Myriam D. Jutras and Maxim Lamirande. We thank Professor Y. Engeström for his invaluable comments and insights, “Fonds de recherche du Québec – Société et culture” 2015-NP-180771 funded this work.

8 References


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