geometrical parameters and the chosen material. The interaction in Phase 2 was mediated with the DREW (Dialogical Reasoning Educational Webtool) platform [32] (cf. Figure 5), discussed below.
Even though DREW was not developed for collaborative *design* situations, it provided the communicational means and *argumentative support* for the project review debate. DREW is composed of different modules, three of which were employed for the experiment described here (cf. Figure 5): a synchronous chat (support for the discussions between the three designers: bottom left), a shared text editor (for describing the common solution and the table of constraints: top left), and an argumentation diagram tool: right. This last module consists of an interface for constructing argumentation diagrams that include one or more theses (phrases in boxes) and arguments that attack or defend them (other phrases in boxes that point to the thesis in question). An example from our experimental design situation is shown in Figure 5 in the original French. Prior to the experiment, the three designers received training on how to use DREW and thus any initial problems they had were dealt with before we recorded their interaction.

## 4 CORPUS OBTAINED

In this section, we present the elements of the corpus we gathered during the collaborative design experiment described above. In addition to supporting communication and argumentation, DREW captures the designers' interactions into XML trace files, chronologically saving their graphical and verbal exchanges. This is crucial for later interaction analysis.
Figure 6 shows such a sequential recording, augmented by an initial Rainbow analysis we performed. The first column is the intervention number (591 total interventions). The second shows the date and time, the third column reveals the designer in question, the fourth column shows the actual content of the designer action and finally the fifth column tells us which tool the designer used. The last column shows the Rainbow categories we attributed by hand and through consensus. As our goal was to explore using Rainbow for the analysis of a new interaction type (collaborative design) in order to extend the framework, inter-coder reliability was not performed.

| N° | Time | Designer | Chat or Argument Graph intervention content | Tool | Rainbow |
|---|---|---|---|---|---|
| 100 | 15/04/05 10:26 | Bob | i don't like solution c | chat | **5. Opinions** |
| 101 | 15/04/05 10:27 | Bob | y:because you don't have a good torque | chat | **6. Argument** |
| 102 | 15/04/05 10:27 | Alan | ah well i like that solution | chat | **5. Opinions** |
| 103 | 15/04/05 10:27 | Bob | if there's a drive shaft shoulder | chat | |
| 104 | 15/04/05 10:27 | Bob | we'll have | chat | |
| 105 | 15/04/05 10:28 | Bob | good precision but we won't be able to manage the pushing effort | chat | **6. Argument** |
| 106 | 15/04/05 10:28 | Bob | unless the tooling is really precise | chat | **7. Explore and deepen** |
| 107 | 15/04/05 10:28 | Bob | do you see what i mean? | chat | **3. Int. Management** |
| 108 | 15/04/05 10:28 | Bob | makes the box Bob.731.1 | grapher | |
| 109 | 15/04/05 10:28 | Bob | begins editing the argument Bob.731.1 | grapher | |
| 110 | 15/04/05 10:28 | Alan | we're supposed to argue on the graph aren't we? | chat | **4. Task Management** |
| 111 | 15/04/05 10:28 | Bob | edits argument Bob.731.1 : Name = pushing effort so transmissible torque not well managed Commentary = Could you add something more? | grapher | |
| 112 | 15/04/05 10:28 | Bob | ends editing the argument Bob.731.1 | grapher | **6. Argument** |

*Figure 6. A partial extract of the designers' computer-mediated interaction using both the chat and the argument graph*

The part with a bold outline illustrates how Bob adds an argument (a box with text) to the graph: "pushing effort so transmissible torque not well managed". Bob does not include a comment. He will later mark this argument as being against acceptance of solution C, the thesis (not shown). We notice that Alain says "we're supposed to argue on the graph aren't we?", but Bob is already adding his argument to the graph. For this short extract, no new categories were needed. Note that category 6. is attributed to the last element of the intervention series that makes for a semantic whole (intervention n° 105 (103-105) for the chat and intervention n° 112 (108-112, excluding 110) for the grapher). In fact there are two arguments: one in favor of a drive shaft (precision) and one against (pushing effort).

This trace file was the principal object of our analysis for the work in this article. Although we will not present their analysis here, other elements also gathered included a paper and pencil drawing from each designer and a description of the solution chosen by him as well as a description of the constraints that this solution takes into account. Designers were asked to modify these documents after the collaborative interaction and this result was also collected. After the experiment, each designer was individually interviewed and these interviews were transcribed.

## 5 DESIGN INTERACTION ANALYSIS FRAMEWORK: RAINBOW-D

Our analytical objective was to perform Rainbow analysis on our designers' computer-mediated interaction trace in order to extend the method — originally elaborated to analyze pedagogically oriented argumentative debates, — to the analysis of collaborative synchronous design. Our motivation for doing so was firstly our belief that designers' interactions included a great deal of arguments for and against different solutions (cat.6), opinions about them (cat.5), and justifications for them, etc. (cat.7). However, Rainbow was developed for analyzing debate where argumentation is the task *per se*. In the case of collaborative design, argumentation is indeed fundamental, but we claim that the core task around which argumentation is based is the proposition of elements of the solution for designing the product and the evaluation of these elements. We therefore propose a slight modification of categories 6 and 7 (including subcategories), which form the *task* under analysis; other Rainbow categories remain the same. As a bonus, Rainbow-D retains the seven-color scheme. Figure 7 shows definitions and examples for the initial proposed modified framework.

| Categories | Definition | Examples taken from our corpus |
|---|---|---|
| **6.1 Argument mobilizing (part of) solution** | The suggestion of a solution element that is argumentatively oriented for the product being designed. | Chat element: "i think we should keep the drive shaft shoulder [4 the axle precision]"<br>Graph element: "solution with drive shaft shoulder" |
| **6.2 Argument mobilizing criterion** | An argument mobilizing a particular criteron for a solution element of the product being designed | "we'll have good precision, but we won't be able to manage the pushing effort" |
| **7.1 Explore and deepen (part of) solution proposition** | Different types of justifications of arguments in terms of solution elements, (e.g. breaking down the solution element into component parts, choosing the physical material of different parts of the solution) | The solution with shaft shoulder and cone ; with shaft shoulder and key |
| **7.2 Explore and deepen criterion** | Different types of justifications of arguments in terms of criteria for satisfying a solution element. | "unless the fabrication is really precise"<br>"and tooling is not that expensive after all" |

*Figure 7. New categories for Rainbow-D (D for Design).*

Concerning the new category 6, both chat elements and graphical elements can be coded as either argumentatively oriented solution elements or arguments mobilizing criteria for evaluation. However, as the chat example of 6.1 shows in Figure 7, the choice of a dominant pragmatic function for each intervention is not always obvious. Here, the example "i think we should keep the drive shaft shoulder 4 the axle precision" consists of an opinion, a proposition for the design *and* an argument (that is not completely made explicit) in favor of the proposition. Alternatively, utterances can be separated. In addition, we see that the analyst must reference contextual knowledge not explicitly present in the dialogue to understand how keeping the drive shaft shoulder is good for axle precision in order to know it is an argument. Category 7 is a first attempt at typifying discursive operations performed on arguments that employ constraints to respect and criteria to satisfy for proposed solutions.

## 6 CONCLUSIONS

In accordance with Blessing & Chakrabarti's [5] criticisms on design research mentioned in the introduction, our first goal was to render explicit the underlying paradigms and assumptions of an analysis approach when transposing it from the intersection of two disciplines (language sciences and educational psychology) to another (research on design). We have thus described the theoretical foundations of conversation and interaction analysis and their influence on the analysis of computer-mediated human interactions. Secondly, we have proposed an extension of a particular analytical method: the Rainbow framework, originally elaborated for analyzing pedagogically oriented societal

debates. Our application of Rainbow to a corpus issued from a semi-experimental design situation (inspired by an industrial project review) allowed us to suggest analytical categories specific to design and therefore extend Rainbow to Rainbow-D (for design). Our current task is to apply Rainbow-D to a new corpus (the Volvo corpus referred to earlier) in order to appreciate to what extent we are able to account for designers' interactions in an authentic project-review industrial situation. As DREW was not used in this new corpus, we expect differences in how the participants structure their argumentation. Once our analytical method has been validated (through inter-coder reliability), we will be able to perform descriptive analyses on our corpus and understand how designers' co-construct their interactions through their use of social and physical resources. It is only through this characterization of existing processes of activities and reasoning (using the aforementioned foci for analysis) that we will be able to form hypotheses about improving these processes through the modification of methods and/or tools. Finally, a new industrial interaction embodying our modifications will be recorded; we will apply Rainbow-D to it and compare the results to the initial Volvo corpus in order to evaluate our proposed modifications. In our view, Rainbow-D is a first step towards understanding the activities and reasoning of designers although we plan on performing more detailed qualitative analyses on how participants organize utterances classed within particular categories, notably 7. Explore and deepen, the heart of argumentative debate on product design.

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