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MOBILISING CRITERIA IN ARGUING ABOUT PRODUCT SOLUTIONS: A MOTOR FOR DESIGNER CONVERGENCE DURING A PROJECT REVIEW?

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1. Introduction

In the current context of market globalisation, companies are less and less able to perform in-house single-site management of all aspects of the design of a particular product. In an attempt to become more competitive, different companies or multiple sites of large companies share product elaboration and distribution in an integrated way, from suppliers of raw materials to final consumers. This relatively new concept, called extended enterprises [Browne, Sackett and Wortmann, 1995], implies the development of a collaborative mode of design in which all phases of product life cycle (definition, fabrication, etc.) are integrated and developed simultaneously. Today, this type of concurrent engineering has taken the place of sequential engineering. The growth of new communication technologies allowing for rapid and distant information transfer has made such a change possible. In this context, the work of designers changes considerably. On one hand, they must use new technologies to communicate, and on the other hand they must learn to cooperate and to integrate requirements of other actors involved in product elaboration. In addition to their professional competencies in solving design problems (mechanical, electrical, etc.), designers must now demonstrate abilities in negotiating and in arguing with other actors of the design process and in manipulating new communication tools. Thus, design activity has evolved; it is no longer simply a technical and scientific activity but it also integrates new dimensions — both human and technological.

The ongoing process of such a design activity is generally 1) asynchronous where actors from different professions involved in the design process work separately and 2) synchronous where these same actors meet in order to make and validate design decisions (typically during project reviews). In addition, designers are either co-located or communicate at a distance. The preliminary work presented here focused on the analysis of a short extract from a synchronous distant project review between two French sites of Volvo.

The primary objective of this article is to understand and describe the argumentative mechanisms that designers use to evaluate proposed product solutions and come to a consensus in the social, scientific and technological context described above. In particular, what types of interactions do designers participate in during project reviews? What is the role of criteria mobilized during argumentation and used for evaluating solutions? Is it possible to see any regularity in how a group of designers come to agreement on a particular solution part before addressing another? Our final aim is to identify moments of decision making, and to model the dynamics of interactions by which designers mobilize criteria and therefore collectively construct common knowledge allowing them to converge and make

a decision. Modeling this process will enable us to propose methods and tools to support designers during synchronous phases.
In what follows, we present our theoretical framework, the project review situation we observed at Volvo, our analysis method and our first results. Finally, we conclude and give perspectives for future research.

2. Theoretical framework

In this section, we briefly describe our theoretical approach combining socially situated and distributed cognition with a view of argumentation in collaborative design interactions.
Our goal is to analyze the co-construction of argumentative reasoning in a socially organized activity where the participants' objective is to come to agreement. Our theoretical focus is on the principles of coordination in such an activity system, but also on the informational content of the interactions that are involved in achieving the participants' goals [Greeno, 1998]. In fact, we are looking to describe what Lave and Wenger [Lave and Wenger, 1991] call community practices. These are regular patterns of activity in a community, in which individuals participate. In our case, the community is the gathering of the members constituting the project review.
Argumentation has been proven to be central in collaborative design interactions as the different models of design rationale will attest Lee and Lai [Lee and Lai, 1996]. For example, according to the QOC model [Maclean et al, 1996], a question is a problem and alternatives to the question are called options. Criteria are used in argumentation to either support or refute an option. Our own work ([Lund, Prudhomme and Cassier, 2007]; [Prudhomme, Pourroy and Lund, 2007]) has shown 1) how arguments mobilize either criteria or (parts of) solutions and how both criteria and (parts of) solutions can be explored and deepened (see results section) and 2) how the dynamics of criteria and solutions can be illustrated in argumentation patterns.

3. Project review situation

We observed a project review meeting at AB Volvo in the business areas Renault Trucks. It took place at the 2 sites shown in Figure 1. (Blainville, near Caen, and St Priest, near Lyon).

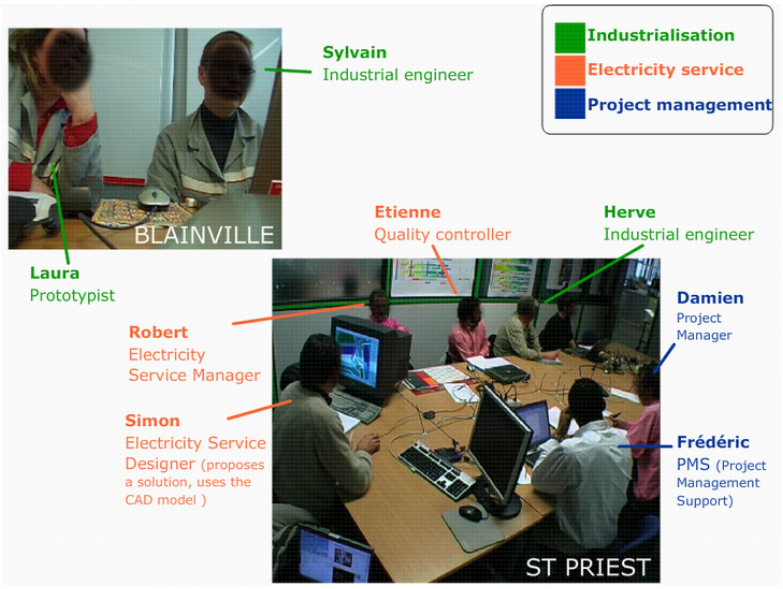

Figure 1. Role of participants on the 2 sites Blainville and St Priest

The aim of a project review is to validate design solutions elaborated by specialized designers. In the project review we observed, called AMS for '*Acceptation Maquettage Série'* (Accepting Serial Prototyping), the solution was presented by St Priest to Blainville in a shared distant computer interface (the computer screen at the left of the bottom photo shows the solution). The solution had to be validated by the people working in Blainville. They needed to verify if the 3D-model could be built by factory workers on assembly lines. Each person had a specific role (see Figure 1). The project manager had the most complete view of the project and ran the meeting. A person called PMS (Project Management Support) took notes of the decisions made during the meeting. One designer is specialized in the domain of electricity and he generally presented his solution with the representation of the 3D model (available for all experts on different screens). This designer was accompanied by his boss, an electricity service manager. The extract we analyzed for this article lasts 5 minutes and occurs in the beginning of the project review. Designers are speaking about the routing of electric cables in the cabin of a truck.

4. Analysis method

We elaborated a typology of activities using work from the COSMOCE project through an analysis of a pedagogical collaborative design situation [Metz, Renaut and Cassier, 2006]. The research in this project was supported by the studies of Hohmann [Hohmann, 2002], Darses and Falzon [Darses and Falzon, 1996]. We also used the Rainbow-D method (D for design), originally elaborated to analyze interactions during situation of debates in design [Lund, Prudhomme and Cassier, 2007]. We articulated these 2 typologies trying to remove redundant notions and distinguishing the form and the content of interactions. For us, an interaction has a specific nature, the form, and treats a particular topic, the content. Interactions with the same content can have different forms. For example: designers can speak about a solution using a tool or not, and through a proposition or through an argumentation. The content is still "the solution" but the form changes. Thus we distinguished 2 levels: Form of interaction, and Content of interaction. We identified 5 types of interactions (cf. Table 1); and the contents: Project, Task, Tools, Solution, Criterion, Communication, Social-Relational. We define forms of interactions in the next table.

Table 1. Definitions of interactions

Categories	Definitions	Example
Proposition	A designer proposes a new part of solution or a criterion. This proposition is evaluated positively or negatively.	"And if we put studs in place of screws ?"
Explanation	A designer describes and defines what he proposed.	"The holes are here, one here, one here, so what it would be judicious, it would be having a pre-alignment or a pre-positioning of the cover"
Opinion	Designers say if they agree or disagree with a proposition or an argument.	"all right"
Argumentation	Expression of an argument or a counter argument to a proposition.	" because it's going to block, I have looked it"
Deepen argumentation	Expression of an argument or a counter argument to another argument.	"It's a problem of manipulation because it's too heavy. »

We filmed 2 hours of the project review meeting with 6 cameras on the 2 sites. We recorded sounds with one microphone on each site. We also gathered general information about each participant and about the global process. We synchronized four of the best video recordings we obtained and made a transcription of the synchronized video. We transcribed dialogue and usage of the 3D model of Catia™ (cf. Figure 2Figure 2. Synchronized video of Volvo AMS).

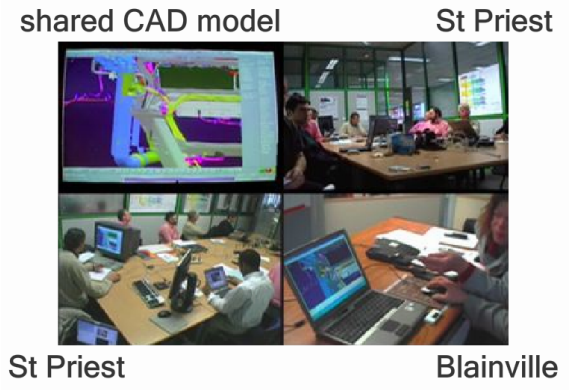

Figure 2. Synchronized video of Volvo AMS

A video of the CAD model is in the left upper corner. This model is shared between the two sites Blainville and St Priest, but only the designer of the electricity service can control it. Other designers have to ask him if they want to change the view or zoom on the picture. In the right upper corner and bottom left corner, we can see two videos recorded in St Priest at the same time, one full-face and one from behind. In the bottom right corner, there is a video recorded in Blainville. We carried out the coding on the transcription, consulting simultaneously the video, and we coded on the 2 dimensions interactions form and content (cf. Figure 3).

N°	Time	Participant	Interaction	Form	Content
9	*00:22:05*	**SYLVAIN**	You see in the upper part?	Expl	Solu
10	*00:22:07*	**LAURA**	A little overhang	Prop	Solu
11	*00:22:08*	**SYLVAIN**	Above… above the fuse box, you make a small overhang here at this place yes a small overhang of 1 centimeter where we are going, and so in the cover top we make a small hole which…the small hole which is OK… thus it enables to put in place and then to pin up, to put the screws de …is it possible?	Prop	Solu
12	*00:22:31*	**DAMIEN**	It must be possible	Opin	Solu

59	*00:24:58*	**DAMIEN**	I have a question here, it's surely on the 636, we had seen that, imagining the electric connector which is on the left revolves and touches the sheet metal… it's doing sparks here.	Argu	Crit reliab
60	*00:25:14*	**ROBERT**	The left one?	Expl	Solu

Figure 3. Extract of the video transcription

In this transcription, the intervention number is on the left, followed by the time of the intervention, the participant and the dialogue itself. The two columns on the right are reserved for coding. The first column is for interaction form and the second one is for the content of the interaction. In this example, LAURA begins to speak about a solution to fix the cover top of the fuse box; she is speaking about a little overhang. We coded it as a proposition of solution because she's proposing a new element to ameliorate the fuse box. The next intervention is also a proposition of a solution. SYLVAIN agrees with LAURA and he helps her to explain and develop her proposition. The next interaction, from DAMIEN, is an opinion. DAMIEN approves the proposition of LAURA. In the second example, we can see that DAMIEN is mobilizing a criterion to evaluate negatively the proposition. He is attacking the proposition of the place of electric connectors because, according to him, they can touch a metal part of the cabin and it's dangerous. He is mobilizing the criteria of reliability.

5. Results

5.1 Dynamics of the interactions

In order to see the dynamics of interactions, we used the software ActogramTM to analyze our coding. We defined a color for each kind of interaction form. As we are interested, in this article, in the dynamics of argumentation, we decided to not initially account for interactions with content of task, project, tools, communication and social-relational. Here is presented the timeline we got (cf. Figure 4).

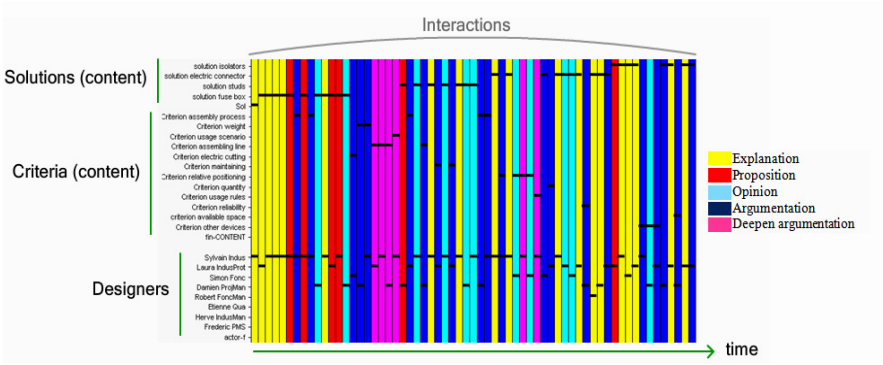

Figure 4. Coding timeline of the extract

This timeline presents the sequences of interactions on a temporal axis. The bottom curve indicates which designer is performing the interactions. We can see that on this extract Etienne and Herve don't participate. Robert speaks just one time. Sylvain, Laura and Damien are those who lead the meeting. The top curve shows the content of interactions. We identified 11 criteria and 4 parts of solutions. The criteria are *weight*, *maintaining*, *assembly process*, *electric cutting*, *quantity of electric connectors*, *fixation on assembly line*, *usage scenario*, *reliability*, *available space*, *relative positioning*, *usage rules*, *others devices contacts*. The new elements of solutions we identified are: the global solution, which is the *global box*, then *the box and the top cover*, the screws then *the studs for fixing*, *the electric connectors* and *the isolators*. We can see on this representation that the color blue, dark and light, and the color yellow are predominant. These colors are respectively the colors of argumentation, opinion and explanation. This representation clearly shows that interactions are solution-argumentation based, confirming the problem-solution co-evolution process design model. We also show that this extract could be divided in two phases. Indeed, a decision, about the solution to fix the fuse box, is made during the discussion. After this decision, the subject of discussion is totally new, it deals with the electric connectors. We decided to analyze these two phases separately (cf. Figure 5 and Figure 6).

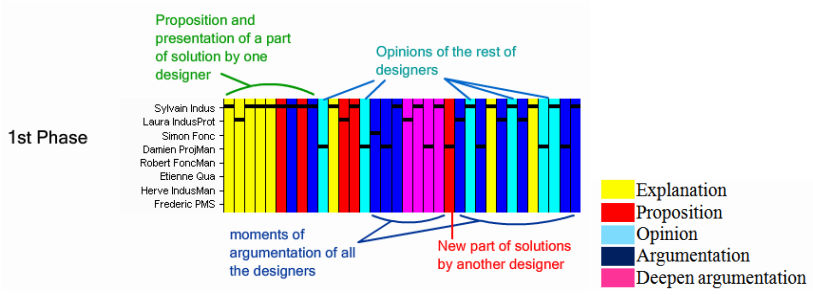

Figure 5. Timeline of the 1st phase, Fuse box and Studs

This analysis shows there is a moment of presentation and proposition of the solution at the beginning of the recording. This proposition is led by one designer, Sylvain, and the rest of designers give their opinion on the proposition. We see also that all the designers participate in the argumentative process. Another interesting result is that we can see the emergence of a part of a solution after a moment of argumentation deepening. We therefore have a hypothesis: does the argumentation deepening allow designers to find new solution elements? Even if the analysis of the second phase doesn't give any information on this subject (cf. Figure 6), this question will have to be addressed in the coming analyses of other corpus extracts.
On this part of the timeline, we see the same dynamics as in the first part. We can see that one designer is speaking about a part of a solution and other participants evaluate this proposition giving their opinion. The argumentative process is still an alternation of interactions of opinion, explanation and argumentation. We know that a decision is made at the end of the second phase but the analysis of interactions doesn't give us information about the nature of the process allowing this decision making. We have studied the form of interaction, now we are going to focus on the content of interactions and more specifically on the knowledge dynamics.

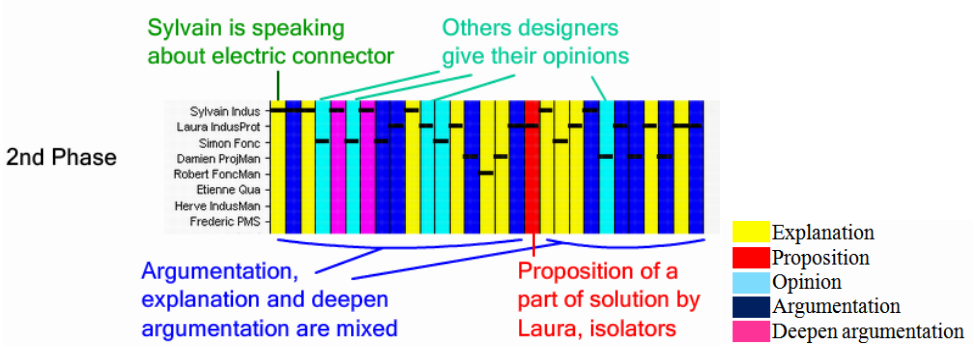

Figure 6. Timeline of the 2nd phase, Electric connector and Isolators

5.2 Knowledge dynamics analysis

In order to perform analyses of knowledge dynamics, we maintain the distinction between criteria and solutions and study when both are just mentioned and when both are explored and described. We use a method presented by Prudhomme, Pourroy and Lund, [Prudhomme, Pourroy and Lund, 2007], and we apply it to the Volvo project review context (cf. Figure 7 and 8). We decided to make one representation for each phase of the extract and in this way we obtained two layouts (cf. Figure 7 and Figure 8). The rectangles represent the solutions and the ovals represent the criteria. The dark squares are used for the descriptions of a solution and the light-grey ones refer to the deepening of descriptions of a solution. The dark ovals indicate the criteria mobilized to evaluate a solution and the light-grey ovals refers to the deepening of description of criteria. Links from element A to element B are positive if A is in favor of B, negative if A is an attack on B, or neutral if they are neither. We used this legend to build a representation of the project review interactions and our goal was to specifically indicate all the solutions as well as the criteria used to evaluate them.
The first phase begins by a negative evaluation of the elements of solutions with the ergonomics criteria. This negative evaluation leads to a new proposition for the part of the solution "bloc + Top cover" (including a specific shape). After this, there is a negative evaluation of this new part of solution with the criterion "electric cutting". While they are looking for a solution that satisfies the ergonomics criteria, designers interact about the definition of ergonomics and are led to speak about a "usage scenario" on the assembly line.

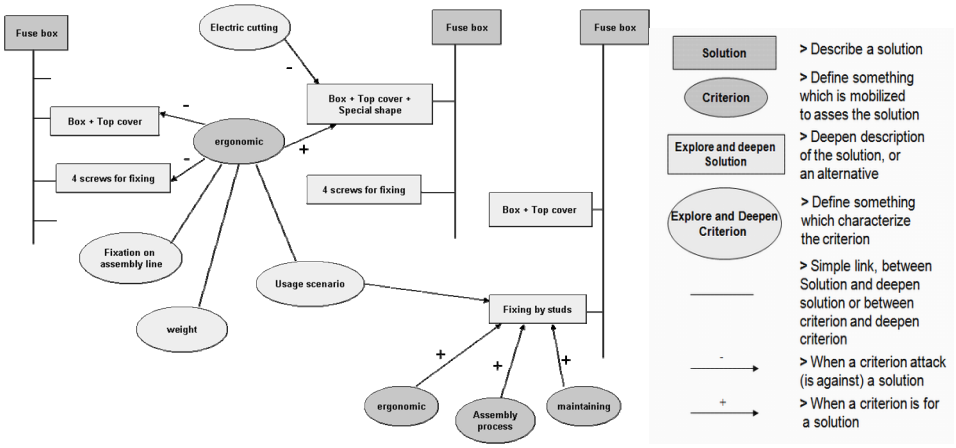

Figure 7. Knowledge dynamics of the 1st phase, Fuse box and Studs

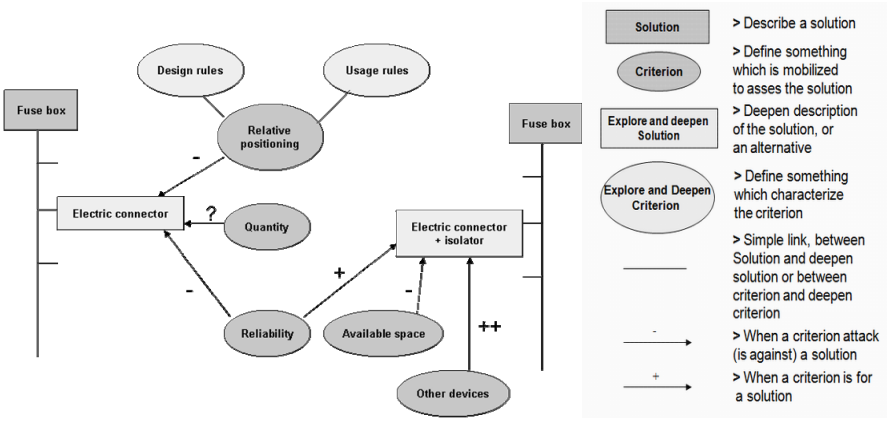

Figure 8. Knowledge dynamics in the 2nd phase, Electric connector and Isolators

This criterion makes the designers return to the first solution with the elements "bloc + top cover" but they change the solution element "4 screws" by introducing the new solution element "fixing by studs". Three positive evaluations validate this proposition. Two questions emerge from this process of solution building: what is the role of deepening descriptions of criteria when arguments support a negative evaluation of the solution? And what is the role of the criterion "usage scenario" (instead for example of the use of controlling a specification list, recommended in design) in the convergent process in this phase?

In the second phase, we notice that a succession of negative evaluations leads to the emergence of a new solution element. In particular, the criterion of "reliability" seems important in the definition of the new part of the solution "electric connector + isolator". Afterwards, even if this part of the solution is negatively evaluated with the "available space" criteria, the fact that it was used in "other devices" (seen as a possible scenario from a usage point of view) makes for a global positive evaluation.

In these two phases we can see that the dynamics of convergence have similarities. Many arguments have a criterion for content and the criteria are principally used in arguments. It seems that criteria are mobilized only to argue. They aren't proposed nor are they explained. One of our assumptions is that criteria are not directly evaluated. On the timeline, no opinion refers to criteria. We think that criteria are evaluated through deepening argumentation. The analysis of knowledge dynamics shows that in

the project review context, solutions are in the center of discussion and are evaluated with many criteria. The design review process can be seen as a co-evolution of solution and problem definition. Our analysis confirms the weight of specific criteria (to be defined for a particular context), and questions the role of the criterion deepening process in decision making. At least, it seems that a usage scenario is more important for designers than a specification list when it comes to making decisions.

6. Conclusions and perspectives

We have shown that the elaboration of a solution in a project review seems to take a path through a succession of evaluations. These evaluations are structured around criteria. In their quest to satisfy these criteria, designers must explain them and propose new solution elements. Certainly, the knowledge dynamics shown in this extract must be confronted with the analysis of other extracts. But if we can find regularities in the dynamics convergence in other situations, we may be able to see which factors allow for convergence and decision making thus allowing us to define indicators of convergence and achieve our second goal: modeling designers' agreement process on the path to a specific solution. To this end, we are carrying out equivalent analyses on the other extracts of the same Volvo corpus. Furthermore, we are looking for a new collaboration with an industrial SME (Small Medium Enterprise) in order to compare the results of the Volvo analysis with the results of a new study in a new context. We hope to find a common interaction pattern in these different situations, thus illustrating the generic scope of our results.

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