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DISTRIBUTED COLLABORATIVE DESIGN: ANALYSIS OF A STUDENT EXPERIENCE

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1. Introduction

Companies are more and more looking for creative and innovative products. Therefore, they opened their doors for innovative ideas that may lie outside their own boundaries. Especially, students form a good resource for this purpose. Student innovation competitions provide a vehicle for the firms to expose their technical problems in order to find innovative solutions. The competition "24h de l'Innovation", organised each year since 2008 by the French University ESTIA in Biarritz is one of them (http://www.24h.estia.fr/). The aim of this challenge is to work within teams, with maximum ten members in each, on different innovation projects during a 24h period. The projects are proposed by companies and cover a wide range of different engineering problems, such as: designing a new product, designing a service or redesigning an existing solution. Two groups of students from Grenoble University of Technology participated to this competition and carried out new product development projects.

Analysing the people collaboration during design projects is one of the core competencies of the G-SCOP laboratory. This paper then presents the analysis of the 24h experience based on part of the laboratory's existing knowledge. The course of the activities of both teams on their respective projects has been analysed, and some themes are defined which might have positive or negative effect on design activity were identified. These themes have been analysed within the scope of distributed design [Brissaud and Garro 1998] and collaboration functional spaces [Salber et al. 1995]. The questions below were tried to be answered:

- which themes are related to which collaboration functional space;
- what were the effects of distribution on the identified themes.

This paper is an analysis of an empirical design experience. It does not aim at putting forward a new theoretical framework or a new model, but presents a case study analysed with two existing frameworks, which are distribution and functional spaces. The approach adopted by the authors was to:

- participate the 24h hours design experience;
- lead a reflexive analysis on the course of the event and to identifty remarkable points;
- analyse the identified remarkable points with the chosen frameworks.

The paper is organised as follows. Firstly, the competition is described in more details. Then, the theoretical background of the analysis is presented and the methodology is discussed. In section 4, the findings of the analysis are presented. Finally, the last section represents the conclusions.

2. Design context

Both teams were composed of students with different backgrounds (industrial engineering, information systems, operational research, etc.), educational status (engineering students, masters and PhD students) and roots (cultures, languages, etc.). Each team had a representative in Biarritz (where the competition handled out), whereas the rest of the team stayed at the G-SCOP laboratory in Grenoble. This laboratory is equipped with facilities that allow those representatives to communicate during the competition with the rest of the team. The teams could also benefit from the resources of the laboratory, such as rapid-prototyping machine or CAD software tools. The experiment started at 2 pm Friday the 23rd and finished at 2pm Saturday the 24th October 2009.

One team carried out the development of a new anchorage system for traffic signs, while the other team worked on an limited edition of an alcool bottle for Christmas time. Both teams managed a product development process from concept definition to prototyping [Ulrich and Eppinger 2004]. Indeed, they started by collecting customer needs and identifying competitive products. They also managed creativity sessions and investigated the feasibility of different concepts. Finally, they designed a solution with CAD tools which was prototyped with stratoconception (a rapid prototyping process of layers of solid/solid type) (Figure 1).

Their projects were quite similar to real design projects due to time and ressources contraints, mixed design teams (multi-language, multi-culture, differents backgrounds etc.), distributed/collocated, synchrone and asynchrone collaboration environments. However, it differenciates from the reality that there was, for example, no budget consideration or career competition between design actors. Moreover, the time constraint and the competiveness were quite extreme and exaggerated compared to industrial design projects.

Figure 1. CAD modelisations and prototypes of the anchorage system and the bottle

3. Theoretical background

3.1 Functional typology

As Salber et al. mentioned, the interactions in collaborative design projects might be represented with the following three functional spaces: communication, coordination and co-operation [Salber et al. 1995] (see figure 2).

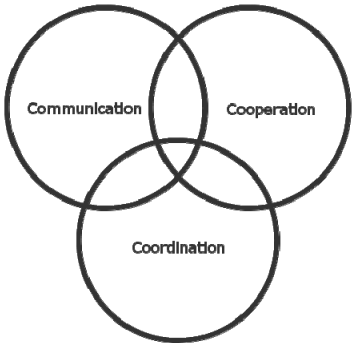

Figure 2. Functional typology (adapted from [Salber et al. 1995])

Based on the previous researches [Mechekour et al. 2006], [Hanser 2003], [Laurillau 2002] the three functional spaces are defined as following:

- *Communication space*: This space offers design actors the possibility to exchange information, knowledge and know-how during a design project. This exchange might be formal (e.g. meetings) or informal (e.g. discussions at the coffee break). These exchanges are essential for the creation of the "awareness", also named "team consciousness", i.e. a mutual perception that allows each team member to know the state of the group and its shared objects. Communication supports the activity of the team, by allowing cognitive and temporo-operational synchronisation [Hanser 2003] [Darses 1994], which are the basis of the two other spaces.
- *Co-operation space*: This space, also named "production space" in literature, describes the actions performed by the team on the shared objects within a common space and timeframe. These objects can be for example ideas, documents or prototypes.
- *Coordination space*: This consists of management of design team. This covers the division of the tasks to be achieved within design team and time period. In this space, sequences of synchronous and asynchronous tasks are also defined.

These spaces are also interrelated.

3.2 Distribution during a collaborative work

According to Brissaud and Garro, design activities are accomplished with the help of knowledge, resources and actors [Brissaud & Garro 1998]. These three dimensions are naturally distributed in time and space, but also between them (see figure 3):

- Prudhomme et al. define knowledge as "the personal relationship one constructs with an object" [Prudhomme et al. 2007]. This knowledge is distributed in actors depending on their technical and cultural background, skills, history and so on.
- Knowledge is distributed in resources, which can be tools (software tools, etc.) or intermediary objects (such as sketches, written documents, etc.). Intermediary objects help to translate, represent and manipulate the design actors' knowledge [Vinck & Jantet 1995]. According to Hanser, the choice of the intermediary object is directly influencing the content of the transmitted message [Hanser 2003]. On the other hand, because each tool is used according to a particular need, one might conclude that knowledge is also distributed in them.
- Resources are distributed in actors, as, within a project, team members may have access or not to an intermediary object or a tool.

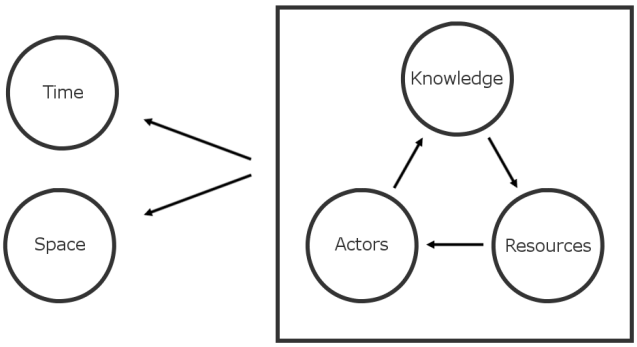

Figure 3. Distribution during a collaborative work

4. Methodology

Our study fits into Schon's [Schon 1983] reflective practice concept which is associated with learning from the experience. He distinguishes reflective practice two different phases: reflection-in-action (while doing something) and reflection-on-action (afterwards). The aim of this empirical study was to analyse our participation to a collaborated design activity in order to reinforce our existing knowledge, with Schon's words "reflection-on-action".

In order to gather data about the design activity, participants were asked to perform a descriptive study. They were asked to write down (between three and four pages) their experiences and impressions about the competition, based on three functional spaces: communication, cooperation and co-ordination. It was a voluntary activity that in total nine participants has taken part. Deeper analysis of this descriptive approach allowed us to identify common mentioned themes during the design activity around these spaces. Afterwards, a more detailed analysis was realised in order to define the effects of the distribution between actors, resources and knowledge on the defined themes during the project. In summary, the methodology consists of two main phases:

- Phase 1: Determining the main themes emerged around functional spaces thanks to the descriptive study
- Phase 2: Defining the effects of the distribution between Actor-Resources-Knowledge on the main themes.

5. Analysis and results

5.1 Main themes emerged around functional spaces

In this section, eight themes to be considered during collaborative design projects are defined. These eight themes, which were frequent among the individual feedbacks, are the followings: language use, personality influence, planning, roles definition, tasks definition, client relationships, documents sharing and prototyping. In what follows, we represent the classification of these items according to functional spaces (see figure 4).

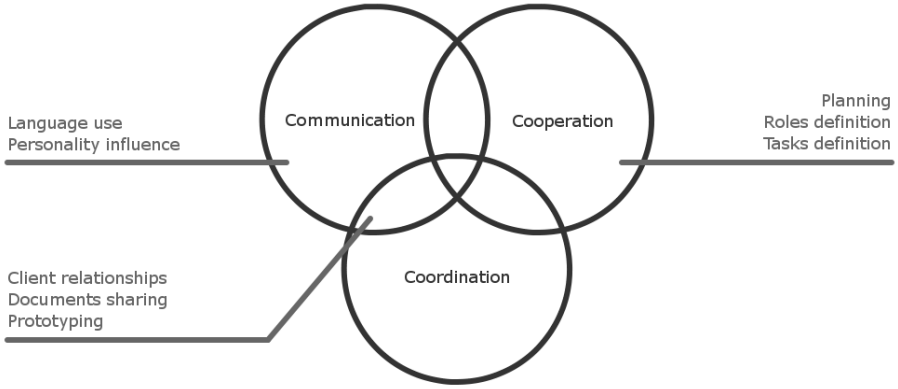

Figure 4. Distribution of the themes in functional spaces

Communication:

One of the themes emerged in communication was the difference in spoken languages. As mentioned previously, the group's members were from different roots. Then, each group had to decide the language they will use as verbal communication tool. The group in which both English and French were used highlighted the importance of language for an effective communication. They claimed that difficulties in verbal communication inhibited the "team consciousness".

The other theme was the influence of the personality. The groups' members claimed that the personality of the person in question (if he is shy, dominant, etc.) was influencing the communication. Because there was no formal hierarchy in groups, then the communication of the members was largely influenced by their personality. However, when roles were clearly defined, the personality tended to be less influent than the status of the team member.

Coordination:

There were three main themes discussed in this space: planning, roles and tasks definition.

The roles definition theme labels to the roles that participants would play, which were pre-defined and spontaneously generated along the competition.

The tasks definition theme refers also to what was pre-defined during the preparatory meetings and what really happened during the competition.
The last theme is planning. Each group had several meetings before the competition to decide how they would be plan the 24h period. Because it would be difficult and time consuming to work with 10 people during the whole period, each group has decided to create some sub-groups that would be responsible to realise predetermined tasks in a limited time period. This planning evolved during the competition. Tasks parallelization and sub-groups creation helped members to be coordinated within the group.

Coordination and Communication:

The presence of the client during the project has shown to be crucial for the effective communication and cooperation. While in one group the client was integrated and has been a part of the team, in other group he was present just at the beginning and the end of the project. This difference between two groups affected the taken decisions.
Another theme was document sharing, which refers to the production and sharing of physical intermediary objects between group members. Document sharing, after asynchronous tasks, was needed for communication in order to allow cooperation
The last theme in this space is the production of prototypes, which might be physical or virtual. Representation of ideas through prototypes was important to enrich communication. They also offered the possibility to cooperate around them.

5.2 Distribution between Actor Resources and Knowledge

In this section, distribution model, which is described in section 2.2, is applied to the previously identified themes. In what follows, we will use this formalism "X → Y" to label "X is distributed in Y" (see figure 2). The different abbreviations A, R, K, S and T refer respectively: Actors, Resources, Knowledge, Space and Time.

Language Use

K→A - During the project, one of the main challenges faced by one of the groups was to manage the different spoken languages. In one group, two languages were spoken (French and English), which was a source of misunderstandings between the members. Because of the time pressure and the fatigue, French-speaking members usually switched into their native languages. Thus, the foreigners usually felt lost during the discussions. Even if French-speaking members forced themselves to speak in English in order to integrate English-speaking ones to the team, it was not easy for them.
However, while the team needed a specific knowledge, the group tended to adapt to the language of the member who has more knowledge on the topic. For example, when the group needed CAD tools, the group spoke in English, because the member who has more knowledge on this tool was an English-speaking person.
On the other hand, the group in which the spoken language was French, the level of the French speaking between foreigners defined the acceptance of their ideas in the group. That means some ideas of the members who were not speaking frequently French, were rejected by the group, even if they were innovative ideas. To sum up, the spoken language was one of the most important "tools" directing the way of communication between design actors.

Personality Influence

K→A - None of the participants had notable knowledge on the technologies mobilised in the product that had to be designed (e.g.: nobody was expert in electronics or in glass industry). However, some of them are particularly skillful regarding design tools or methods. Moreover, there was no defined hierarchy between team members. These impacted the progress of the project. In the first hand, during meetings, where no particular skills were asked, the speaking time was only influenced by the personality of the speaker. The way ideas were expressed had a great influence on the importance the rest of the team gave to them. Confidence of the speaker, his ability to monopolize the speech for a while and his willingness to argue were decisive factors. Thus, due to their personality, some members

had a greater influence on the project, regardless to the quality or relevance of their ideas. In the other hand, once a particular skill was needed (such as ability to use CAD tools or to manage creativity sessions), there was a clear emphasis on the member who owned it. Negative effects on idea representation were erased by the need for this specific skill and by the related status of expert, which provided some credibility to the owner. Encouragement had even be expressed by the rest of the team in the case of shyness.
R→A - Tools (CAD, rapid prototyping machines, etc.) were distributed in different places. To use them, and in order to work at the same time, actors were consequently distributed in these places in some sub-groups. This reformed the hierarchy imposed unofficially in team based on personality, which helped the shy members to express themselves.

Client Relationships

K→A - Each project was proposed by a client company. To allow the team to choose a project, each one was presented with a few sentences. As previously said, none of team members had particular technical knowledge on these topics. Moreover, there were a lot of unsaid requirements, which needed to be known by the design teams. In order to allow each team to learn a bit more about its client, its expectations and constraints, each client was represented by one of its employees, and each team was allowed to collaborate with him. However, according to their timetable, the clients were not available during the whole 24 hours. Thus, knowledge about the project was distributed between a specialist (the client) and the designers (who do not have specific knowledge on the topic). This reinforces the importance of the availability of the client: an autonomous team can not design a product that matches exactly the customer needs. The whole needs are rarely expressed in the specifications. These ones need to be updated during the design process. The absence of the client creates risks in the development process.
A→ST - Moreover, these people were distributed in space and time. The abilities of the two teams to communicate with their clients were different. In a team, the client had few time to dedicate to the project, so that the collaboration with him occurred only two times during short interviews. Thus, he did not follow the progress of the project. In the other team, the client was more available and spent more time with team during the evaluation of ideas. Thus, he followed the progress of the project and helped the team by answering any questions or providing real-time feedbacks to each proposition. Time spent with the client was shorter for other team than this team. Consequently, there were huge differences between the sequences in their design processes: The first team chose a particular solution during the night and met its client in the morning, when this solution was well defined. The client disliked this solution, and was very interested by another one which was rejected during the night by the team. Thus, this team had to come back earlier in the design process and lost a lot of time (Figure 5). The other team did not face such a problem: they spent time earlier with the client to discuss about the constraints and expectations of his company. Moreover, thanks to his availability, the client was involved at each main stage-gate, when decision about the design had to be taken. Thus, the team was able to develop a solution that fulfilled the client's expectations.

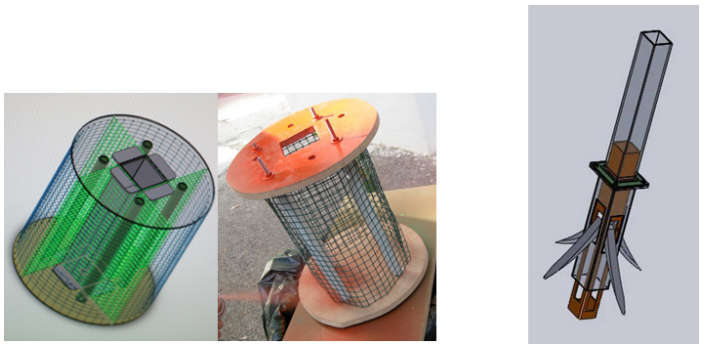

Figure 5. Two different anchorage solutions

K→R. - As mentioned before, the communication tool used by the teams to exchange with their representative in Biarritz were different. The representative from one team could communicate with

his whole team, whereas the representative from other team could only communicate with another intermediary in Grenoble (Figure 6). Thus the client of the first team was able to communicate, even cooperate, with the whole team. For example, he assisted to presentations made by video conference and was able to give his opinion. In the second team, the communication between the client and the whole team had two intermediaries: one member in Grenoble and the correspondent in Biarritz. Space was a real barrier for this team, whereas videoconference nearly abolished the distance.

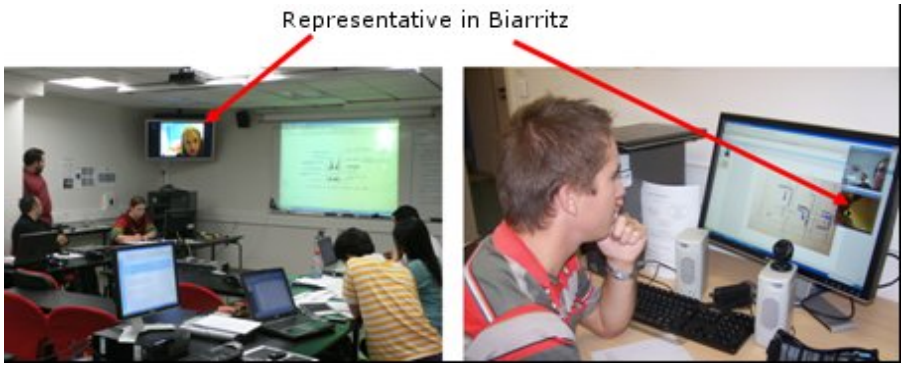

Figure 6. Different ways of communication between teams

Prototypes and CAD files

R→A - The available resources distributed between actors affected the type of the prototype created during the experiment. In order to realize rapid prototypes of the products, two groups had to use the same prototyping platform, which was only available in a limited time period (between 8am and 2pm, at the end of the project). Thus, the groups realized the rapid prototypes after taking the last decision on the product to be developed. Although, in real industrial projects the rapid pro-prototypes are used earlier to evaluate the different solutions, in our case they were representing the taken decision on a product idea. Teams also made prototypes earlier to evaluate solution. Indeed, dough, papers or cartoons were on the dispositions of the actors. By using these resources the groups created less detailed prototypes. The most detailed ones were realized by the usage of CAD tools.

K→A - For the realisation of the less detailed prototypes, any special knowledge was needed. However for the realisation of detailed prototypes, the knowledge of the CAD tools was required. These CAD models were then used in rapid-prototyping process. Because the people in charge of CAD tools were not professionals, the groups had many problems to implement these CAD models to rapid-prototyping process. Moreover, because of time constraint, actors could not improve their skills on tools and use them more efficiently. So team could only rely on members' existing knowledge. Lack of experience in design process as well as technical context could evolve and rationalise the use of prototype in the first phases of project, in order to clarify the ideas or solutions and evaluate them.

K→R - The objective to use a prototype was determined by its knowledge content. This knowledge content should be enriched during the advancement of project. For example, in the first phases of project, the less detailed prototypes were used to represent and evaluate the ideas, to justify the solutions, or to eliminate the misunderstandings. Then the more detailed ones were used to identify technical problems, to calculate dimensions, or to test product feasibility.

Defining the tasks

R→S - The availability of resources to fulfil a task might affect directly on the definition of this task. For example, the presence of laboratory facilities to realise a rapid-prototype affected the way to accomplish the task "realisation of the product prototype". The objective was not only to build a prototype but also to exploit those facilities.

K→A - In the competition, some tasks were defined depending on existing engineering background and knowledge in project management. It was noticed that some phases, like creativity, did not happened as we expected. The group did not succeed to set up a creative ambiance, caused by a lack of experience. Also time constraint pushed team to follow simple solutions instead of deepen the subject and find more creative ones.

Defining the Roles

R→A - The distribution of the resources within the group caused the creation of new roles, which were not defined in advance. For example, the person who was using the tool that allows working with the people at distance played the "intermediate" role in the group. That means he was informing the people at distance about the progression of the project and he was also transmitting their attributions to the group.

K→A - The knowledge of the actors influenced the role attribution in the group. Before the project, some specific roles were defined depending on the particular competences of the actors, such as capacity to use a software program. Even for the construction of the groups, the competences have played an important role. We tried to have the same number of people with CAD model skills in each group. Those people were responsible for the prototyping. Furthermore, some roles, which were not assigned before the project, appeared progressively according to the competences. These roles were created in order to satisfy an unexpected need. For giving an example in one of the groups the spoken language was French, However, for the people who had difficulties to understand, a person speaking fluently English and French, played occasionally the translator role.

Planning

K→A - As the groups had few experience on design project, it was not obvious to define an efficient planning (Figure 7). In particular, they made a mistake when they organised the creativity phases. Some group members worked on the generation of creative ideas, before the others. Thus, when they presented their ideas, the other members, the latter were influenced for the rest of the project by the ideas exposed by the former.

A→ST - On the other hand, some tasks had to be done in specific spaces. Even if it seems obvious, that can impact deeper the planning. Indeed this task can be related to others, which can be done in another place. For example, in one group, the distant member, influenced by time emergency, started the final presentation of the project. Therefore, that influenced the work of some members of the group in Grenoble, who had to take pictures for the presentation, in the same time. If people from Grenoble decided first to prepare the presentation, there would not be such constraints on the tasks organisation.

R→ST - The availability of resources in space and time influenced as well the tasks transition. In our experience, groups had the possibility to use a rapid prototyping tool. It was available only on the second part of the challenge and somewhere else than where we worked most of the time. Clearly the time when we planed the task of making a prototype was entirely depended of these constraints.

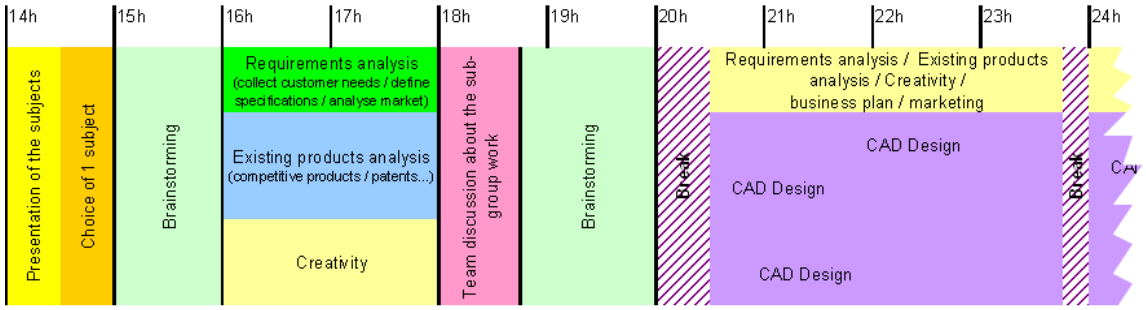

Figure 7. Planning prepared before the 24h experience

Document sharing

A→S - The necessity of capitalisation depends on the actors' location. If the actors were geographically distributed the documentation was more important, in order to inform the progress of the project. This helped the cooperation to go on efficiently.

R→A - Besides, it depended also on the tools needed for capitalisation and document exchanges. In the early of the challenge we had to make a choice between two different capitalisation tools. We chose the tool available for most of us.

K→A - The knowledge of actors about subject of design influences the efficiency and utility of documentation. If the members are from different fields of expertise, the documentation should be understandable for non-expert members. The knowledge of team members about the methods of documentation and capitalisation may influence on the employed tool.

6. Discussion

As mentioned before, this study was a "reflection-on-action". It means that two teams firstly participated to a collaborative design project, and then, they started to observe and interpret their own experiences. So, in this study, the analysers were also the designers. It makes the difference with commonly used design observation researches that the observation is done by external observers. This method offers a new point of view based on designers' own observations during competition.
The descriptive study of the designers is used to identify themes that are felt, remarked and then clarified more commonly by the designers. This approach offers new dimensions on analysis of collaborative design process, which would merit to be more developed. Also, it needs to be enriched, in order to set up a more structured method to extract, clarify and classify these kinds of themes.
However the defined themes were differents in their nature. For example themes like language or personality have unintended impacts; however, themes like planning or document sharing are deliberated themes, which improvement might have positive effects on the the design process.

Table 1. Summary of the themes and their distributions

is distributed in	K	R	A	S	T
K		Client prototype	Language Personality Client Prototype Task role Planning Document Sharing		
R			Personality Prototype role Document Sharing	Task Planning	Planning
A				Client Planning Document Sharing	Client Planning
S					
T					

Table 1 summarises the results of our analysis; classification of the items according to their distribution. There are some empty cells in the table, which signifies that we did not find any associated distribution. It may be expected that in other experiences, which take place in different situations, other types of distribution might be occured. In the table black cells shows the unconsidered distributions such as distrubution of actors on actors.
We propose few observations based on these results that would be interesting to be discussed in more detail. All themes lie in distribution of knowledge on actors,which shows that this distribution needs to be considered more consciously before a similar project. In our experience, it seats more important than ever distribution of actors in space or time, which seemed more troubling before the start of project.
Other fact extracted from this table is the proportion of each functional space vis-à-vis these distribution. Distribution of actors and resources on time or space (See table1: dark grey cells label cooperation) may have to be treated by cooperation techniques, but managing distribution of knowledge on resources (See table1: ligth grey cells label coordination) needs more coordination functions.

Then the question might be askef if we could generalize such associations of functional space with distributions. This competition take place each year, which give us an occasion to repeat this experience. This would help us to prepare ourselves, before competition, by enriching our methodology and focausing our analysis on some specific subjects.

7. Conclusion

In this paper we have presented an analysis of a distributed design experience according to part of the the theoretical background of our Laboratory. In the first section, we introduced the circumstances of our participation in the "24 heures de l'innovation" on which our study is based. In the second section we have presented the collaboration functional spaces and the notions of distributed design that we used in our analysis. Then we have developed the methodology, which is related to reflexive practice concepts. In the fourth section we have identified eight remarkable items that have been impacted by the distribution of design, and then we have studied the impact of the distribution on each item.
The collaboration functional spaces and the notions of distributed design represent two sets of analysis whose combination has allowed us to analyse effectively our collaborative projects. We could explain, with this grid, how the distribution impacted our design projects on the eight points we have outlined.

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References

Brissaud, D. & Garro, O. 1998. 'Conception distribuée, émergence', In Conception de produits mécaniques : méthodes, modèles et outils, ed. Hermes, Paris.

Darses, F. and Falzon P. 1994. 'La conception collective : une approche de l'ergonomie cognitive', GDR-CNRS FROG "Coopération et Conception". Toulouse, December 1st 1994.

Hanser, D. 2003. Proposition d'un modèle d'auto coordination en situation de conception, application au domaine du bâtiment, Institut National Polytechnique de Lorraine.

Laurillau, Y. 2002. Conception et réalisation logicielles pour les collecticiels centrées sur l'activité de groupe : le modèle et la plate-forme Clover, Université Joseph Fourier.

Mechekour, E. H., Marin, P. R. & Masclet, C. 2006. ' Which tool to better support collaborative design? ', In Proceedings of IDMME'06, Grenoble, France.

Prudhomme, G., Pourroy, F. & Lund, K. 2007. 'An empirical study of engineering knowledge dynamics in a design situation', Journal of Design Research, 6 (3): 333-58.

Salber, D., Coutaz, J., Decouchant, D. & Riveille, M. 1995. 'De l'observabilité et de l'honnêteté: le cas du contrôle d'accès dans la communication homme-machine-homme médiatisé', In Actes d'IHM95, Toulouse: Cépaduès éditions.

Schon, D. "The reflective Practitioner", 1983.

Ulrich, K. T. and S. D. Eppinger, "Product Design and Development", McGraw-Hill Higher Education, 2004.

Vinck, D. & Jeantet, A. 1995. 'Mediating and Commissioning Objects in the Sociotechnical Process of Product Design: A Conceptual Approach', In Management and New Technology: Design, Networks and Strategy, eds. D. In MacLean, P. Saviotti and D. Vinck, Bruxelles: COST Social Science Series.

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