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A Cognitive Mapping Approach to Organizing the Participation of Multiple Actors in a Problem Structuring Process

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Abstract Problem structuring methods lead to a better understanding of problems by proposing that individuals engage in a structured process of investigation of such elements as causal relationships, connected problems, and possible solutions. This paper first examines possible ways of organizing the participation of multiple decision-makers in the varying contexts of the problem structuring process. The paper presents an original methodology based on investigating the participants' contributions with respect to the problem explored. This methodology uses cognitive mapping techniques and offers two kinds of support, the first justifying a specific division of the participant set into thematic subgroups and the second providing a basis for further exploration using different problem structuring methods.

Keywords Problem structuring methods · Participation · Cognitive mapping · Facilitation

1 Introduction

Numerous methodologies, models and decision supports aim to facilitate group decision-making and/or problem structuring processes. The nature of the facilitation and the choice among these methodologies depends on several factors, such as the nature of the problem context in which the facilitator intervenes and the demand that is

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made of him/her (Cropper 1990; Bennett 1990), the kind of models that are implemented, the role that information technologies are supposed to play (Fjermestad 2004; Chidambaram and Jones 1993; Dickson et al. 1993; Nunamaker et al. 1988) and more generally the nature of the desired interactions between facilitators, models and participants. Problem structuring methods (PSMs) are expected to produce innovative representations of problems that highlight unexplored solutions. More generally, PSMs lead to a better understanding of ill-structured (as defined by Rosenhead and Mingers 2001) problems (as defined by Rittel and Webber 1973 and Ackoff 1962) by proposing that individuals enter into a structured process of investigation of such elements as causal relationships, connected problems and relevant possible solutions. In order to support such a structured process, PSMs generally allow people to see things from different alternative perspectives, without any specialized skill requirements and permit progressive local adjustments (Mingers and Rosenhead 2004).

A glance at PSMs literature reveals the numerous possible contexts in which these methods may be applied (Mingers and Rosenhead 2004). However, few of these studies demonstrate a systematic preoccupation with concrete methods for organizing the participation of multiple participants in the problem structuring process. There has been some research dealing with the way to adapt and to use PSMs within specific participation contexts: for instance, contexts with large participation groups (Shaw et al. 2004) or contexts with multi-organization teams (Franco 2009 or White 2002). Concrete facilitation constraints and issues have also been investigated in studies about PSMs (Franco 2009), Group Decision Support Systems (Huxham and Cropper 1994) and operational research models (Taket 2002; Phillips and Phillips 1993). Recent work in the field of collaborative engineering have proposed a collaboration engineering pattern language called ThinkLets that produce predictable patterns of interactions among team members (Kolfschoten et al. 2006; Briggs et al. 2003); these studies have also provided facilitators with useful material.

One part of this paper examines the possible ways of organizing participation in the problem structuring process. The paper also presents a methodology based on investigating the participants' contributions to the exploration of the problem. This methodology uses cognitive mapping techniques that offer two complementary support mechanisms. On the one hand, the methodology helps facilitators to cluster participants into thematic subgroups, and on the other hand, the methodology provides an analytical basis for deeper exploration of the problem.

The ideas discussed in this paper are strongly connected to the concept of "organizing participation", including such activities as assigning roles to participants and scheduling participant interventions. Since this concept (organizing participation) has not been widely studied in itself, we provide a detailed explanation in Sect. 2. In this section, we also review the possible methods that facilitators can use to organize participant interactions in a problem structuring process. In Sect. 3, we present an original cognitive-mapping-based methodology that could be used both for organizing the participation and structuring a problem. This methodology is illustrated in Sect. 4 with a real case, and in Sect. 5, we provide our conclusions about this methodology and detail related future research perspectives.

2 Organizing Participation: Principles and State of Art

Facilitating a problem structuring process, given an ill-structured, complex strategic problem, requires organizing the way participants interact. It also requires asking questions about the way the facilitator should interact with the participants by using support systems within the problem structuring process. In this paper, we focus on the way to organize the participation of multiple actors within problem structuring processes. By "organizing the participation", we mean providing answers to the following possible (non-exhaustive) list of questions:

2.1 In Which Type of Activity Will Each Participant Become Involved?

Several different activities can be distinguished within the problem structuring process, including exploring thematic areas, identifying actions, assessing actions, prioritizing actions, and choosing actions. It is entirely possible, for example, to ask an expert to intervene in the action assessment steps, but not in the action prioritization steps.

2.2 What Role in the Process Will be Held by Each Participant?

The participant's role is partly linked to the type of activity being performed. Of course, such roles make sense within the problem structuring process only if all the participants, including the decision-makers and facilitators, feel that it is relevant to assign different responsibilities to the different members of the group.

2.3 What Will the Schedule of Intervention be for Each Participant?

Naturally, the scheduling of the interventions of each participant depends on the previous elements (i.e., the role of each participant and the type of activity in which participants get involved).[1]

2.4 What Medium Will be Used to Support the Interaction Within the Process?

The relationships between the facilitation and group support systems have been studied, and numerous earlier studies have dealt with the effects of facilitation on the use of group decision support mechanisms (e.g., Bostrom et al. 1993; Griffith et al. 1998). Others studies have shown the contributions in computer-aided contexts show the effects of the communication medium on group perceptions (Chidambaram and Jones 1993).

[1] An interesting related study was published in the 1990s dealing with a scheduling-aid support mechanism for inexperienced facilitators (Antunes et al. 1999).

2.5 How Will the Participants be Broken Down into Sub-Groups and What Will the Role of Each Sub-Group be?

The methodology we present in the next section focuses on this last point, and thus we discuss it in more detail in the following paragraphs.

Organizing participation by working with sub-groups of individuals rather than individuals can be argued to be one of the key factors of success in any collective context. Several earlier studies have highlighted the superiority of groups over individuals in the decision-making process. This has been discussed in terms of risk taking (Cecil et al. 1973; Whyte 1956) and performance (Nutt 2002). Specifically, Massey and Wallace (1996) have shown that, given an ill-defined problem, groups produce better results than a single individual. In particular, groups have the potential to examine a problem from different points of view, which is one of the advantages of collective work (see also Eden et al. 1981). With a large participant set, organizing participation can be seen as simple pragmatism but dividing a group of individuals into sub-groups is not easy (see Stumpf et al. 1979 for a discussion of this point in terms of the problem structuring process), especially if the group is seen as a single unit, with no particular basis for determining relevant participant clusters (e.g., Jackson and Keys 1984 or Belton and Pictet 1997).

Carley (1986) has indirectly shown the importance of group composition in collective cognitive processes. Individual representations of a problem are the basis for interactions between participants, and thus, group work consists of making the individual cognitive schemes converge to produce a collective cognitive representation, implying that the better the group composition, the better the convergence. This kind of research has led us to think that determining each sub-group's composition is a fundamental concern. It is certainly reasonable to assume that group participants will find a way to revise their representations if they are able to communicate with other participants with whom they feel at ease.

In management research, the question of team work composition has been extensively explored over the last several decades. Shaw (1981) showed the effects of diversity (e.g., of race, gender, personality, and/or competencies) in group composition, explaining the benefits of group diversity in terms of diversifying the elaboration of actions and solutions. Wanous and Youtz (1986) built indicators to measure the quality of the decisions made by groups with respect to the different levels of diversity in the group composition. Hinds et al. (2000) explored different hypothesis about the relationship between group performances and group composition in voluntary organizations in which participants are able to choose the teams they belong to. Several factors were tested in this study: similarity between participants, complementary participant competencies, and mutual participant knowledge, for example. The results show that, in part, participants prefer to belong to a team in which other members share similar characteristics with them (e.g., racial characteristics).

The multiplicity of participants, with their diverging interests and diverse problem representations, has also been recognized as a source of complexity in ill-structured problem contexts (Rosenhead and Mingers 2001). However, to our knowledge, the organizing of the interventions of multiple participants in the problem structuring process has not yet been widely studied in itself. In fact, only in a few studies has the organization of participation even been partially addressed.

Hart et al. (1985) highlighted some interesting information in their framework for generating ideas. The different steps of their methodology lead to the generation of new ideas, which participants then cluster, or classify, by theme. Different thematic workshops are then planned to facilitate the organization of the participation. The authors recommend composing the workshop groups in order to maximize the diversity of perspectives. However, no reference to the individual contributions of each participant in the generation of new ideas is mentioned, and no systematic way to determine the composition of work groups is described.

In other studies, individual phases and collective phases are alternated to facilitate the structuring of the problem. The individual phases highlight individual beliefs and cognitive representations, while the collective phases allow these beliefs and representations to be integrated in a collective whole. For example, Langfield-Smith (1992) proposed a 2-step protocol for constructing collective cognitive maps. First, each individual participates in individual cognitive mapping sessions using the self-Q technique (Bougon 1983), from which a list of themes emerges. The different themes are then ranked according to a logical order, producing an individual causal map. Second, collective workshops are organized to consolidate the individual cognitive maps through collective negotiation about the conceptual elements that will be inserted in the collective map. During this negotiation process, participant sub-groups are created to work on assigning the conceptual elements on each individual's map to one of three categories: consensual elements that can be incorporated into the collective map without any disagreement, elements with different names but the same meaning, and non-consensual elements whose incorporation into a collective map provokes strong participant disagreement. As long as the sub-group cannot agree on the assignments to these categories, the negotiation process continues. Once a consensus is reached, all the sub-groups gather in a plenary session to find causal relationships between the concepts on the list, and a collective cognitive map is constructed.

This protocol was tested by its developer, who observed that the sub-group sessions did not converge in a reasonable time, calling the protocol itself into question. In response to this difficulty, Langfield-Smith suggests that a collective cognitive mapping technique should not try to describe a global collective cognitive structure. However, the author did not discuss the influence of group composition on the convergence times needed for the negotiation process. In our opinion, this influence should have been discussed, at least as a potential hypothesis explaining the long convergence times.

Tegarden and Sheetz (2003) have developed a collective cognitive-mapping technique whose first step is designed to collect concepts relevant to the explored problem from the individual participants. Such an organization of the participation requires that subsequent collective and integrative phases be included in the process. However, other studies bypass these collective and integrative phases, as it is the case with methodologies using aggregation or comparison tools to examine individual cognitive maps. Ozesmi and Ozesmi (2004) and Coban and Secme (2005) have proposed methodologies with aggregation tools, while Markoczy and Goldberg (1995) have proposed one with a comparison tool. Although these methodologies do save a lot of time, the role of the facilitator is proportionally quite important. It is certainly possible to allow group members to discuss the elements of comparison provided by the tool; however, in our opinion, the final result runs a great risk of being biased. Sometimes, rational analysis tools are expected by some participants to give the right solution to the problem, which is not their real purpose (see Roy's (1993) discussion about decision aiding). Still, this expectation could lead some participants to interpret the results provided by comparison or aggregation tools incorrectly.

Some of the studies mentioned above use explicit methods avoid bias due to group composition. For example, the Tegarden and Sheetz (2003) method uses random assignment to determine group composition in order to avoid bias. Langfield-Smith (1992), on the other hand, changes the group composition within the same problem structuring process.

3 A Cognitive-Mapping Method for Organizing Participation

This section presents a methodology based on the use of a cognitive mapping technique. This technique has widely been used and studied in various contexts as part of problem structuring methods (see Eden (2004); Eden and Ackermann (2004); Sahin et al. (2004); Coban and Secme (2005); Tegarden and Sheetz (2003); Kwahk and Kim (1999); Borroi et al. (1998); Carlsson and Walden (1997); Swan (1997); Verstraete (1996); Lee et al. (1992); Bougon and Komocar (1990), for example). Fiol and Huff (1992) indicated that a cognitive map could be represented in different forms. In most cases, it consists of graphic image, representing the connections between ideas, items or concepts. Generally, a cognitive map cannot be reduced to the image itself. The mapping often is a valuable process that helps to develop collective thought, to clarify a negotiation process (Eden 1988) and/or to highlight the cognitive structures within an organization (Weick and Bougon 1986).

In our methodology, we use cognitive mapping as a support for organizing participation in a problem structuring process. Used in a specific manner, cognitive maps can give information about the contribution of each participant to the exploration of a problem. We use this information to help the facilitator form relevant participant sub-groups.

The methodology we present in this section integrates several of the contributions of the authors discussed in the previous section. First, the ability of a set of individuals to produce a collective cognitive structure is reinforced by dividing the participant set into relevant working sub-groups. Second, the methodology alternates two types of phases, first eliciting individual perspectives or problem representations, which establishes the specific cognitive identity of each individual, and then integrating these diverse points of view into a single entity, providing a single concrete explanation of the problem.

In order to illustrate the purpose of the methodology, let us consider the following context. Suppose that a group of individuals is involved in a preliminary stage of a problem structuring process. A problematic situation must be investigated, and the first steps of the process are exploratory in nature. A group of top managers of a firm wants to pinpoint the oncoming threats and opportunities in one specific market. In a preliminary stage, before making any decisions, the group wants to structure this question, isolating the thematic groups that may require further investigation. The group also wants to build a common vision of the question by synthesizing the group's converging and diverging views of the problem. The methodology we present provides a framework and an analysis tool, which helps the facilitator to organize the involvement of each individual at the beginning problem structuring process in terms of the individual's potential contribution to the problem exploration.

Our methodology has five steps, which are described in the following paragraphs.

Step 1: Collection of a set of items

The objective of the first step of the methodology is to collect a set of items connected to the problem. Here, by *item*, we mean what is classically meant in cognitive mapping applications: contrasting ideas, concepts (Eden 1989) and/or whatever could be used as a language to represent part of the problem (a notion derived from Kelly's personal construct theory (1955)). These items are collected via a preliminary series of individual interviews. These interviews are quite important despite the fact that they are time consuming.

Most of the research about cognitive mapping techniques insist on the importance of building a confidence-based relationship between the facilitator and the participants (Eden and Simpson 1989). These individual interviews during initial stages of the process give the facilitator the opportunity to elicit individual opinions about the problem, which is one of the way to increase trust. Confidential face-to-face interviews also allow participants to speak about politically sensitive issues (Grinyer 2000), which is positive at this early stage of the process. Of course, these interviews require specific facilitation skills. In addition, in order to collecting useful information during these interviews easier, participants are asked to provide items in a unique format: the author (the participant who has given the item) of each item provides a label (a short title) and a short definition or illustration of what is meant by the label.

At this phase, there is no need for participants to furnish a coherent exhaustive view of the problem, including all its implications. All that is required is to provide a very personal representation of the problem.

The facilitator has to make sure that each participant knows explicitly the objectives of this preliminary phase in terms of the following phases. More precisely, each participant interviewed should be aware that the collection of items will both contribute to the collective problem structuring process and be the basis for organizing the participation within this problem structuring process.

Step 2: Elaboration of a thematic map of the problem

At the end of the step 1, a set of items has been collected. This set contains the ideas and concepts provided by the participants. Some items may be seen by their respective authors as redundant or similar to those provided by other participants. Others may be interpreted as connected but not similar, for example, the items contributing to describe the same sub-issue of the general problem. On the other hand, some items may be seen as completely distinct. The purpose of the step 2 is to use these varied perceptions as inputs to complete the output of the step 1 in order to build a map

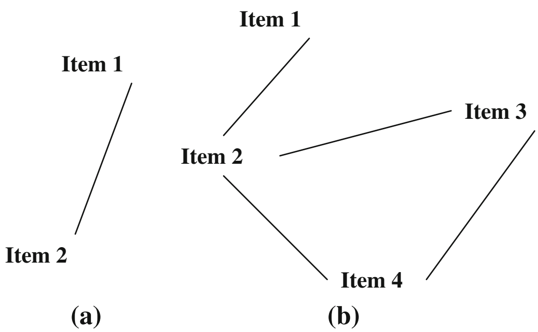

Fig. 1 **a** Basic representation of a proximity relationship between 2 items. **b** Basic representation of a whole set of proximity relationship between several items

of the themes connected to the problem. Each participant is asked whether his/her proposed items are similar or connected to some of the items proposed by the other participants. The rule that governs the elaboration of the map is easy: if the author of item 1 perceives the existence of a proximity relationship with item 2 and if the author of item 2 perceives the same proximity relationship with item 1, then the graphical representation shown in Fig. 1a is created.

The entire set of proximity relationships between items makes it possible to elaborate a graphic image (Fig. 1b) that we call a thematic map. This map represents a collective vision of the themes connected to the problem as it is perceived by all the participants, though this vision may not necessarily be "common" at this step of the methodology. This map is both the output of step 2 and the input for the next step.

It is possible to implement step 2 by organizing a second series of interviews. For variety of reasons, these interviews should be done with small sub-groups of participants instead of the face-to-face interviews used in step 1. First, working on relationships between items could take quite a long time, especially if the set of items is large and the average number of items per participants is high. Second, this kind of interview has the advantage of allowing participants to interact, getting the meaning of what has been said in step 1 by the other participants directly from them. Since, at this stage, the facilitator does not have sufficient material to help him/her to determine the composition of these small groups, a random composition seems to allow a useful enough thematic map to be constructed; this map is a kind of prerequisite for further problem structuring work. The thematic map provides information that helps to organizing the interactions between participants in a way that enriches the following steps of this problem structuring process.

Step 3: Analysis of participants' contributions and structuring of the workshops

Clusters of items may appear on the thematic map obtained in the previous step. By "clusters of items", we mean groups of inter-connected items that have no relationship with any of the other items of the map. Figure 2 represents an example of a thematic map for which three different clusters were obtained during the step 2. In this figure, the facilitator has noted under each item the coded name of the participant who provided the item so that the contribution of each participant in steps 1 and 2 will be apparent.

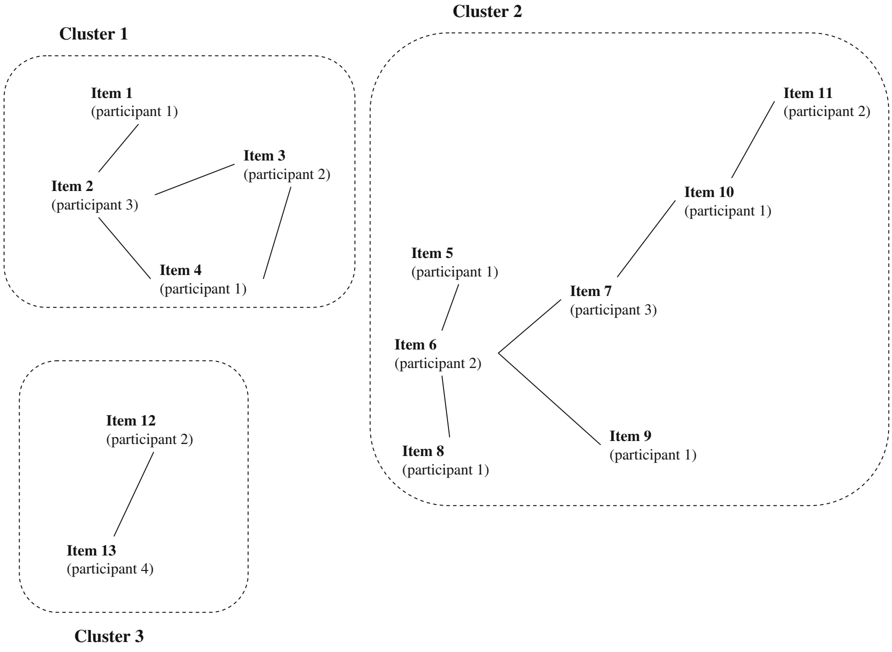

Fig. 2 Example of a thematic map with 3 clusters

The contribution of each participant in one particular cluster may vary a lot. Some participants may contribute a small number of items to the cluster, while others may propose numerous items. The nature of contributions may also be diverse, with some items "attracting" numerous other items (as it is the case for item 6 in cluster 2) and other items being linked to only one or two items (as it is the case for item 11 in cluster 2) (Fig. 2). In other words, certain items (e.g., item 6 in cluster 2) have the potential to integrate what has been said with a large number of other items. Other items (e.g., item 11 in cluster 2) have the potential to enrich the description within one cluster of the part of the problem that has been designated by participants. We propose to use these properties in order to highlight the contribution of each participant i in one cluster t. We thus introduce two indicators: K_i^t and D_i^t.

Let K_i^t be the indicator measuring the ability of the participant i to provide items that can be used to synthesize the global meaning of cluster t . K_i^t depends on the nature of contribution of the items provided by participant i in cluster t. One possible way to calculate K_i^t would be the following. For each item provided by participant i in cluster t, the number of clusters that would appear if this item (and the relationships

Table 1 Number of clusters appearing for each eliminated item in cluster 2

Items	5	6	7	8	9	10	11
Numbering of clusters appearing	1	4	2	1	1	2	1

between this item and the others) were eliminated from the cluster are counted. For the example shown in Fig. 2, the result for cluster 2 is given in Table 1.

Then K_i^t is calculated for each participant i contributing to cluster t as the maximum of these numbers. For this example, the value K_i^2 for each participant is given in Table 2.

The average number could have also been used, but this solution was not retained because at this step it is important to identify the highest potential contribution of each participant, even if this potential is based on very few items.

Now, let D_i^t be the indicator measuring the ability of the participant i to provide items enriching the exploration of the global theme represented by the items in cluster t. D_i^t is the maximal value of the shorter path (as it is classically calculated in graphs) between each of the items provided by participant i in cluster t. For the example referred to above, it is possible to calculate the shorter path for each pair of items for each of the participants that contributed them (Tables 3, 4, and 5).

The value D_i^2 for each participant in this example is given in Table 6.

The higher the value of D_i^t, the greater the diversity of the items provided by participant i contributes to cluster t. Indeed, when the diversity of items provided by one participant is high, the contributions of participant i will potentially allow other participants to link their concepts to the cited thematic area and will also potentially

Table 2 Calculation of K_i^2 for each participant contributing to cluster 2

Participants	1	2	3
K_i^2	2	4	2

Table 3 Shorter path between items provided by participant 1

Items of participant 1	5	8	9	10
5	0	2	2	3
8		0	2	3
9			0	3
10				0

Table 4 Shorter path between items provided by participant 2

Items of participants 2	6	11
6	0	3
11		0

Table 5 Shorter path between items provided by participant 3

Items of participants 3	7
7	0

Table 6 Calculation of D_i^2

Participants	1	2	3
D_i^2	3	3	0

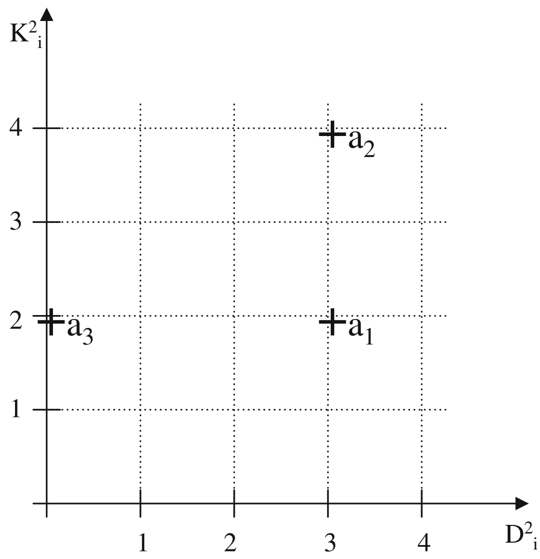

Fig. 3 Diagram (D_i^2, K_i^2) of the cluster 2

elicit other points of view. The diagram of (D_i^2, K_i^2) can be constructed as shown in Fig. 3.

The quality and the nature of participant i's contributions are represented as a point on the (D_i^t, K_i^t) diagram. It is now possible to examine the contributions of each participant and to identify the arguments to be used to justify the composition of the sub-groups working on the themes represented by the different clusters.

The following strategy could be used to perform these justifications. In Fig. 3, participant 1 is rather important to the exploration of the theme represented by cluster 2 because his/her ideas have both a high integration potential and a high enrichment potential for this theme. It would be more interesting to involve this participant in a sub-group that is going to work on cluster 2 than it would to involve participant 3, who tends to be "dominated" by participants 1 and 2. In this particular example (which is not very relevant because of the small number of participants), if sub-groups are designed to work with pair of participants, it would then be appropriate to put participants 1 and 2 in the sub-group working on the theme represented by cluster 2, assigning participant 3 to another sub-group working on another theme.

Step 4: Thematic workshops

A possible composition for each sub-group has been determined and justified using the (D_i^t, K_i^t) diagram from the previous step. In step 4, each sub-group is expected to explore one particular theme corresponding to the items of one particular cluster on the thematic map. The items in one cluster and the connections between them are not necessarily explicit enough to get a clear vision of the boundaries of the theme to which the cluster corresponds. Participants in each sub-group work to determine the limits of these boundaries in the same manner employed to define what is called "decision area set" in the Strategic Choice Approach methodology: "areas of choice within which decision-makers can conceive of alternative courses of action that might be adopted, now or at some future time" (Friend 1989).

In the literature, many tools have been proposed for analyzing the position of each item in a cognitive map. Eden (2004) has reviewed some of these tools. These tools can be used, for example, to identify problem networks within causal maps, and are essentially designed for conceptual studies and not for participation exploration. Still, measuring the degree of centrality of each item in a cluster can help to highlight the necessity of focusing on a particular item in order to find the most integrative item and the best way to define one or several thematic areas.

Step 5: Collective consolidation

Step 5 is the final step and aims at consolidating the outputs compiled during the thematic workshops in the previous step. This consolidation is done through the collective study of the redundancies and similarities between outputs of the thematic workshops. At the end of this step, the boundaries of the different thematic areas are redefined, and the relationships between the themes appear, which in turn leads to the definition of new themes. At this stage, participants should be now prepared to enter into a new phase, no longer exploratory but rather decisional.

4 Illustrative Example

In order to illustrate our methodology, we consider the following real case,[2] in which a set of multiple participants had to investigate a problem: the Board—composed of 10 functional managers of a French industrial firm, specialized in power plant manufacturing—had to determine the optimal size for the engineering division, given the on-going growth of the firm. The board had to decide whether all of the Research and Development projects (including both repetitive mechanical calculation tasks and innovation research) would be accomplished by the division itself or whether some of the work would be outsourced to external firms with whom partnerships would be concluded.

The question of "how to manage the growth of the engineering activity" involved unknown issues. The Board had to explore these issues as part of an ill-defined problem. In concrete terms, the board had to first identify the sub-issues related to the problem in a structured exploration phase. The initial formulation of the problem was rough. Identifying the problem boundaries, its associated issues, and the potential subsequent actions was not an easy task, but the board had to elicit and then structure all these elements.

The Board also had to deal with another kind of complexity because its various members had diverging points of view on the subject. In fact, the initial formulation of the problem was already ambivalent: for some participants, the problem was seen as an operational problem simply related to the size of the engineering team, while for others, the problem was seen as a strategic problem related to the definition of the firm's core competencies.

[2] For confidentiality reasons, the names of the firm and of the participants have not been mentioned in this paper; the project is still on-going.

In a context of collaborative research, we were asked to provide support for this exploration phase. We proposed to implement at least the first four steps[3] of our cognitive mapping methodology to support a double objective: not only determining the problem structure, but also organizing the participation of the Board members to insure an in-depth exploration of each of the themes related to the problem. It seemed that organizing the participation in this exploration phase was one of the major difficulties. Indeed, in this specific context, we had to deal with the following constraint: It was practically impossible to get the 10 members of the board to meet at the same time to work on this problem structuring process.

Step 1: Collection of a set of items

In the context described above, each of the 10 participants was asked to personally provide several items linked to the issue called "Managing the engineering activities in a growth context". Through an on-line questionnaire and interviews, each participant was asked to provide a short label (no more than 5 words) and a short description (no size constraint) for each of his/her items. Each item was automatically coded in order to respect the rule of anonymous contribution.[4] Then a set of items was compiled as shown in Table 7.

As Table 7 makes clear, the contributions of each participant were not well balanced. For example, participant 2 gave 7 items whereas participant 5 gave just 2 items. Certainly, the methodology does not require each participant to give the same number of items, but this can become a problem because it does not help to prevent an unequal distribution of contributions amongst participants. In order to avoid this problem, each participant should be thoroughly briefed about the potential problem, so that each participant will feel that it is in his/her best interest to give the greatest number of items possible. Imposing a fixed number of items would not prevent bias since some participants would give unproductive ideas and the set of items would not be easy to work with. In our opinion, it is more important to have a small number of well-described items (which is the case here: as Table 7 shows, very few items have been left without description) rather than numerous ill-defined items.

Step 2: Elaboration of a thematic map of the problem

A collection of the perceived relationships between items was made through individual interviews. Interviewees were asked to give their opinion about the connection between the items they gave and those given by other participants. Although this operation could be considered as a time-consuming task, it allows participants to have a better understanding of how other colleagues perceive the same situation. At this stage, no common representation has been constructed, but it could be considered that a first step toward a common representation of the problem has been taken. Figure 4 shows the thematic map obtained as a result of step 2.

[3] Step 5 was not sure to be organized because some of the members of the board felt that the small number of participants (10) did not require organizing a final plenary consolidation session. However, step 5 was eventually organized and is now in progress.

[4] For example, the code $c_{i,j}$ would be used to code the jth item of participant i.

Table 7 The set of items provided by the 10 participants

Item code	Participant	Item label	Short description
$c_{10,1}$	10	Added value	What is the added value of our team if too much externalization of R&D activities
$c_{9,3}$	9	Calculation standardization	Relationships with our partners based upon more precise standards (about calculation operations)
$c_{7,3}$	7	Change-oriented minds	High level growth management implies a radical change of mind orientation
$c_{10,3}$	10	Chinese partners	Continue to develop our partnership with Chinese R&D firms
$c_{1,2}$	1	Computer licences	Renew our licences on our different modelling aiding tools
$c_{7,2}$	7	Contracts definition process	Participation of members of the R&D team to the sale process
$c_{2,6}$	2	Contracts renewal	Contracts with our partners have to be renewed
$c_{10,4}$	10	Contracts with actual partners	Complete contract process with our French partners
$c_{8,4}$	8	Control on partners	New partners but numerous way to control the work we externalize
$c_{2,1}$	2	Core competencies	Externalization of our activity lead to one question: what are our core competencies?
$c_{5,1}$	5	CRM improvement	Customer Relationship Management as a way to a better understanding of our R&D program
$c_{3,1}$	3	Culture	Do we have a high level-growth-oriented culture?
$c_{2,7}$	2	Customers	A better understanding of our customers necessary to get to faster processes
$c_{6,2}$	6	Customers	Understanding customers
$c_{2,4}$	2	External facilitator aiding	It could be useful to structuring a deep thought about the way to manage growth with the help of an external decision aiding facilitator
$c_{10,5}$	10	Historical competencies	Let us try to think about what we have always done
$c_{4,3}$	4	Historical image of the firm	Our firm has always been specialised in what is today our core competencies
$c_{7,1}$	7	HRM	Human resources management as an essential piece of the problem
$c_{1,3}$	1	Individual competencies	The R&D team competency is the sum of individual competencies: what are they?
$c_{5,2}$	5	Integration of new partners	We could give to new partners part of our activity
$c_{8,2}$	8	IS improvement	New information exchange procedures
$c_{9,4}$	9	Lead engineer expatriation	What about sending members of our team to part of our Chinese partners
$c_{3,5}$	3	Legal unit	New organizing of the firm unit in charge of legal assistance
$c_{10,6}$	10	Link meeting	Meetings to help coordination between sales unit and R&D team

Table 7 continued

Item code	Participant	Item label	Short description
$c_{3,4}$	3	Mind mapping	Mind mapping tools to help to structuring a collective work about our growth
$c_{2,3}$	2	Motivation	The way we manage growth is a question of individual motivation
$c_{8,5}$	8	New position	Creation of a new position: a link manager between R&D team and sales unit
$c_{1,5}$	1	Partners training	The growth could be correctly managed if we improve competencies of our partners
$c_{6,1}$	6	Partnership	A focus on our partners to help us developing our ability to manage growth
$c_{2,2}$	2	Process	Design new processes for an unknown path of growth
$c_{4,1}$	4	Process redefining	We could be more efficient if the R&D team were early involved in the sale process
$c_{9,1}$	9	Quality process improvement	Implement new quality standards as part of the process redefinition
$c_{3,2}$	3	Retirement	Take into account the next retirement waves in the R&D team
$c_{9,2}$	9	Sales-engineering relationships	No particular comments
$c_{1,4}$	1	Solve 3D-modelling tools	More and more problems with our 3D modelling tools
$c_{8,1}$	8	Strategic issues	Which place for new partners and externalization: a strategic issue
$c_{8,3}$	8	Team in the company	Necessary deep thought about roles of our team in the company
$c_{3,3}$	3	Team-building	A team-building session to increase individual motivation
$c_{4,2}$	4	Total quality management	By reintroducing the customer at the edge of our preoccupations
$c_{1,1}$	1	Training	We have to be more relevant on the training courses we offer our engineers
$c_{2,5}$	2	Training	More training for our freshly arriving engineers
$c_{10,2}$	10	Wages	No particular comments

Step 3: Analysis of participant contributions and structuring of the workshops

Individual contributions were analyzed based on the thematic map obtained in step 2. On this map, four clusters appear. The largest one is the one positioned at the left top corner of the map (see Fig. 4). As shown on the map, this cluster contains 17 items. In order to illustrate the methodology, let us consider what has been done with this cluster,[5] called C^1, of 17 items:

$$C^1 = \{C_{1,3}, C_{2,1}, C_{2,6}, C_{3,5}, C_{3,6}, C_{4,3}, C_{5,2}, C_{6,1}, C_{8,1}, C_{8,3}, C_{8,4}, C_{9,3}, C_{9,4}, C_{10,1}, C_{10,3}, C_{10,4}, C_{10,5}\}$$

[5] The same kind of analysis was done of other two clusters. These analyses and their results are not included in this article.

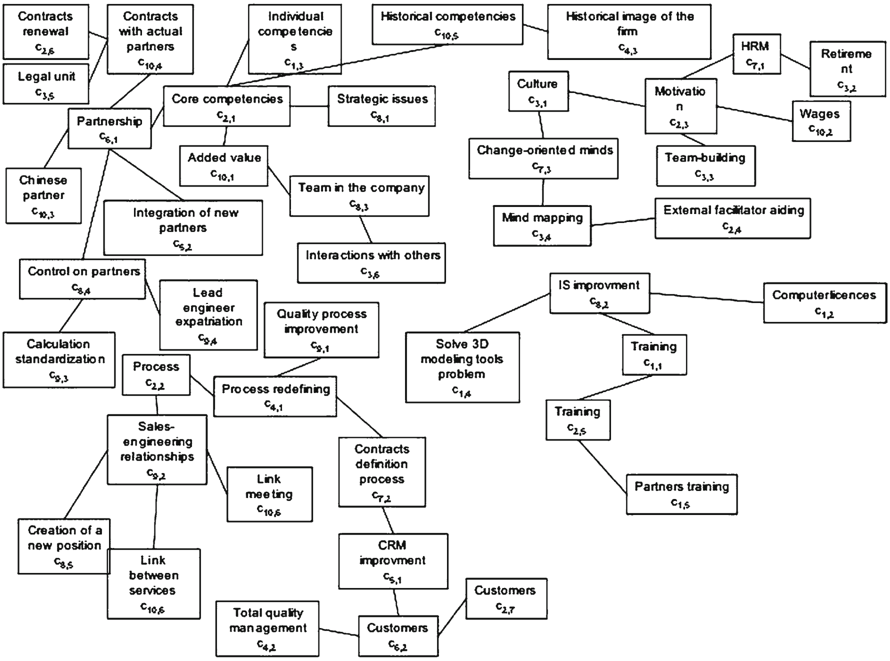

Fig. 4 Thematic map obtained in the real case example

The (D_i^1, K_i^1) diagram for cluster 1, described in Sect. 3, is represented as follows (Fig. 5):

This cluster represents 8 out of 10 participants, which is a precious clue indicating the importance of the thematic point developed through this group of items. As shown in Fig. 3, participants 1 and 7 do not appear to contribute to C^1 . Participants 2, 3, 4, 5, 6, 8, 9 and 10 on the other hand, do contribute to the cluster, each contributing in a different manner. For example, participant 6 clearly has integrative potential since the value of K_6^1 is very high. This participant was previously identified by us and the board as being one of the oldest members of the firm; in the past, he has mostly worked on the firm's external relationships with customers and suppliers. For this reason, it is not surprising to see that he has one of the higher K_i^t values in cluster t . Participant 3, however, does not appear to have integrative potential, although he has contributed items that enriched the definition of the theme represented by the cluster. Indeed, this participant's D_3^1 value is the highest of all the D_i^1 values.

This diagram helped us to form the participant sub-groups for further exploration of the concepts and ideas linked to the problem. Setting a maximal number of participants for each sub-group made it possible to use the(D_i^t, K_i^t) diagram to decide whether the various participants should be included in the different sub-groups working on each cluster. For practical reasons (as mentioned above), the Board did not want to implement workshops with too many participants. It was decided to limit the number of participants in the workshop concerning cluster C^1 to 4. Participants 2 and

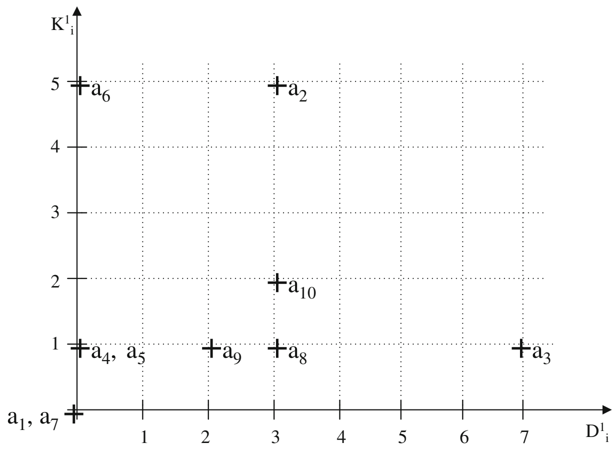

Fig. 5 Diagram (D_i^1, K_i^1) of cluster C^1

3 had to be assigned to the sub-group working on this cluster, since their contribution do dominate the contribution of other participants to the cluster. Indeed, points a_5 and a_7, representing participants 5 and 7, are dominated by points a_2, a_3 (and a_6), either in terms of the value of D_i^1 index or the value of the K_i^1 index. (Excluding participant 5 or 7 from participating in the sub-group on this particular thematic area does not mean that the contributions of participants 5 or 7 would never be discussed. In fact, their contributions may even be central in the final discussion, leading the entire group to focus on the concepts provided by them in this thematic area.) Participant 6 was obviously chosen because of his K_i^1 index value. Another reason also led to this decision: as mentioned above, this participant was clearly the one with the greatest experience in the field of partnerships. Thus, it was not possible to conceive of working on this theme without this participant. Finally, participant 10 was chosen because it seemed that he had a profile that balanced integration and enrichment quite well compared to other participants.

Step 4: Thematic workshops

Three different workshops working on the three clusters were organized. Each workshop had the goal exploring in more depth the theme represented by the items of the assigned cluster. In order to help the sub-groups to do this work, information was provided. Table 8 shows the information communicated to the sub-group working on the cluster C^1 concerning the properties of the items of the cluster. This table indicates the calculation for each item in cluster C^1 of the number of clusters that would appear/disappear if this item was eliminated.

An analysis of this table reveals that the firm had to resolve a dilemma: on the one hand, the firm must look for new kinds of partnerships and new external sources of R&D competencies in order to be able to manage on-going growth; on the other hand, the firm must take its core competencies into account, asking whether or not it is relevant to search outside the company for what the company already has inside.

Table 8 Analysis of the items of cluster C^1

Item code	Participant	Item label	Number of cluster appearing
$C_{10,1}$	10	Added value	2
$C_{9,3}$	9	Calculation standardization	1
$C_{10,3}$	10	Chinese partners	1
$C_{2,6}$	2	Contracts renewal	1
$C_{10,4}$	10	Contracts with actual partners	3
$C_{8,4}$	8	Control on partners	3
$C_{2,1}$	2	Core competencies	5
$C_{10,5}$	10	Historical competencies	2
$C_{4,3}$	4	Historical image of the image of the firm	1
$C_{1,3}$	1	Individual competencies	1
$C_{5,2}$	5	Integration of new parteners	1
$C_{9,4}$	9	Lead engineer expatriation	1
$C_{3,5}$	3	Legal unit	1
$C_{6,1}$	6	Partnership	5
$C_{8,1}$	8	Strategic issues	1
$C_{8,3}$	8	Team in the company	2

Table 8 illustrates two central concepts: core competencies and partnerships in terms of the respective values obtained for $c_{2,1}$ and $c_{6,1}$. These are the two basic concepts of the cluster. Other items with a value higher than 1 but lower than 5 were considered as items that lead to a better understanding of these central concepts. These other items do not always provide new ideas; sometimes, they just offer other ways to say things, and this is precisely what is interesting in this context. Items that are not in the same position, as well as any items with a value equal to 1, were also discussed. These items enriched the thematic investigation because the links between these concepts and the central ones were not always obvious.

Figure 6 represents part of the synthesis that was made by the participants of the cluster C^1 thematic workshop during step 4. For most of what appears in this figure, the output of the work was the planning of different tasks linked to the different issues. The participants of the cluster C^1 sub-group felt the need to give output containing precise indications about the tasks to accomplish after this exploratory phase.

Step 5: Collective consolidation

As mentioned above, step 5 is still in progress. A plenary session will be organized soon. Nevertheless, the search for new R&D suppliers began just few days after this workshop. A working group was set up, and a long selection process has been initiated. This process involves rating a number of small R&D firms working on mechanical calculation that are considered to be potential new R&D suppliers.

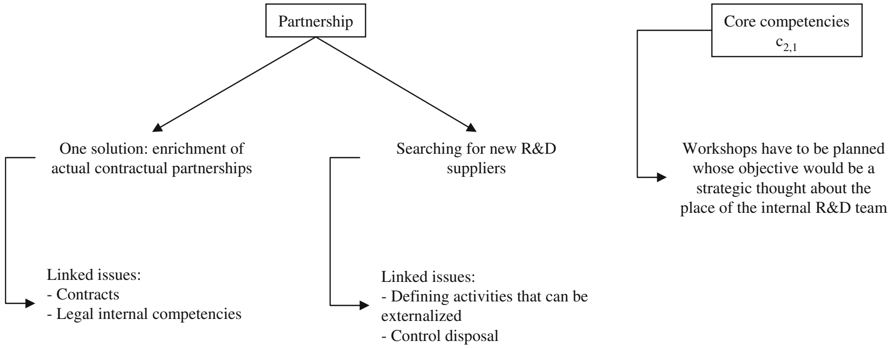

Fig. 6 Output of the thematic workshop about cluster C^1

5 Conclusions

In problem structuring contexts, organizing the participation of multiple group members should be one of the main preoccupations of the facilitator. In most of the problem structuring methods currently implemented, this task is obviously not taken as seriously as it should be. We have not found any research in which a systematic, rigorous methodology is applied to provide, for example, a relevant, justified set of sub-group compositions. In this article, we present a methodology with two main objectives. The first is to support a collective problem structuring process. Clearly, complex strategic contexts are often supported by problem structuring methods. In most of these contexts, the complexity comes from the diversity of problem representations, even within a same organization. Problem structuring methods mostly apply cognitive mapping techniques to capture individual cognitive representations of the problem, but we use them to support a collective process. The second objective of our methodology is to provide tools for analyzing the contributions of each individual group member, which could help determine working sub-groups. Dividing the whole group into small work groups can make a thematic exploration process converge more efficiently. The theoretical background for this hypothesis is linked to research about cognitive approaches to group work, some of which were presented in the introduction.

The proposed methodology should be seen as one of the components in the set of tools used to structure a problem. This methodology could be used as a premise in research done with "soft systems methodologies" or "strategic approaches", for example. Further advances must be made in the way that our methodology articulates with other PSMs. In addition, the methodology could be used in other methodological contexts, thus far closed to problem structuring, such as the definition of the criteria set in multicriteria decision support.

Finally, there is still much work to be done in relation to the way the thematic map of the problem should be constructed. For example, what should be done if no cluster appears at the end of the step 2? We propose to work on elaborating fuzzy maps in which, values representing credibility degrees would be attached by the participants to the connections between items. This is one way to generate maps that allow autonomous clusters to be revealed, even if there are no formal connex components in the graph.

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