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Structuring fragmented knowledge: a case study

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Abstract
When the need to record and track the point of view of different actors in organizational processes becomes a key point for decision makers, a common representation of knowledge from different perspectives and a map of the situation and the decision and action needs could be useful. A methodology that easily and transparently integrates different 'soft' and 'hard' tools in a common knowledge structuring approach is proposed to deal with complexities and uncertainties in a socio-technical contest. The purpose of this paper is to show the potentialities of this methodology in a real case, in terms of organizational knowledge acquisition and structuring in a multi-actor public context, a university faculty, in relation to a radical change.
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Introduction

In 1999, the European Higher Educational sector began a radical change that was called the 'Bologna Process'. The main aim of the Bologna Process was to create a European Higher Education Area (EHEA), based on international cooperation and academic exchange, that would be attractive to European students and staff as well as to students and staff from other parts of the world (The official Bologna Process website, 2007).

The objectives of the Bologna Process were to create comparable degrees, organized on the basis of a three-cycle structure (e.g., bachelor-master-doctorate), to ensure quality in agreement with the Standards and Guidelines for Quality Assurance in EHEA, and to recognize foreign degrees and other higher education qualifications in accordance with the Council of Europe/UNESCO Recognition Convention. The main impact of this European reform in Italy, at an operational level, was the reorganization of didactics in relation to redefining the learning outcomes for each of the three cycles, a new length of the courses and innovative regulations, such as those pertaining to curricular internships.

After several years of intensive change, the head of the IV faculty of engineering at the Politecnico di Torino decided that it was necessary to have an overall view of the new teaching programme from the students' point of view and was also interested in structuring this vision into organizational knowledge to support changes in the management. At that moment, the professors' points of view about the change process and its expected results were well known, but no knowledge was available concerning the students' perception of the contents or organization of the new courses offered by the engineering faculty or of their opinion about the change process they were involved in. The head of the IV faculty

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felt that this was a relevant drawback to the deployment of the reforms that had been defined in the Bologna Process.

Since the eighties, the Politecnico has regularly submitted a questionnaire to students at the end of each course, in order to obtain the students' opinions, but the head of the faculty considered that this procedure was not sufficient, in relation to such an important change, to understand the students' perceptions of the teaching quality in the new organization. The actors who were responsible for the faculty change processes were the faculty head, two people in charge of the Bachelor degree course and the Master of Science programme and another four members of the faculty who were only responsible for some specific functions, such as communication. Students were not involved in the change process, but were involved in the faculty council.

For these reasons, free interviews appeared to be the most effective way of acquiring a global view of the students' point of view. The analysis of these interviews was oriented towards representing and communicating a set of organized and useable informative elements pertaining to the main problematic areas, from the students' points of view, to the members of the faculty management group (the decision structure).

The procedure of knowledge acquisition and transfer to the decision-making structure was organized and developed using a structuring methodology that orients and controls the analyst's approach when multiple points of view and knowledge elements about an ill-structured problem have to be used to identify, structure and represent strengths, weaknesses, limitations, opportunities and threats. Its logical tools are used to reduce complexity and uncertainty, elaborate possible solutions and propose them in communication and decision contexts.

The need to record and track the points of view of the actors who are involved in the organization processes becomes evident for a decisional structure, above all when the objective is to change something in the organization. Understanding how the involved people see the change problem is essential to make better decisions but a structured and validated representation of the various points of view is not easy to acquire or synthesize.

The aim of this paper is to propose, through the case study, a structuring methodology and, above all, one of its logical tools that can easily be used to facilitate the intelligence phase of a decision process and to improve communication between actors and decision makers. A brief overview of the adopted methodological approach is proposed in the first section, while the next section introduces the operational approach that was adopted to organize the interviews. The succeeding section presents the cognitive mapping procedure that was used to synthesize and structure all the acquired elements. The results that were proposed to the faculty head and the other members of the decision structure are described in the fourth section while some remarks are proposed in the Conclusions.

Methodological approach

The initial problem-structuring phase of a decision-aid process is one of divergent thinking, opening up the issue, surfacing and capturing the complexity that undoubtedly exists, and beginning to manage this and to understand how the decision makers might move forward. Then, a more convergent mode of thinking emerges from the complexity, as a distillation of the key factors in a form that is transparent, easy to work with and which can generate further insights and understanding (Belton & Stewart, 2002).

When multiple actors are involved in the decision process, at different levels and with different roles (decision makers, clients, sponsors, other stakeholders), their interaction is sometimes difficult, and in some cases almost impossible. Their points of view, in relation to the situation, can be different, and only a global knowledge of their different visions and representations allows the decision makers to elaborate a valid action. When the problem situation is not structured, the identification of the essential points of view also becomes difficult and can require the support of problem structuring methods, such as the methodologies proposed in Bowen (1998) and Rosenhead (1989) . One such method is MACRAME.

MACRAME, a Multiple-ACtor-RepresentAtion-ModElling methodology, was specifically developed (Norese, 1995) to support understanding, structuring and modelling-validation activities in situations with multiple actors and difficult communication, in which the knowledge elements that are required for decisions have to be acquired from actors who are not involved in the decision process.

MACRAME can activate multiple functions (formulation of the problem, knowledge acquisition, structuring and transfer, model structuring, validation and documentation, and model management, where the term 'model' indicates the formal representation of a specific decision problem and its possible actions) and specific actor analysis and cognitive mapping tools (Buffa *et al*, 1996). It has been used in different ways, over the years, in situations that presented different critical aspects, such as when an initial client's demand proved to be too generic to easily arrive at a clear Problem Formulation or when a problem situation resulted to be ill-structured.

A specific application of the model management function (Norese & Sarboraria, 1998) was used by analysts to develop a model management system (Baldwin *et al*, 1991), that is, a decision support system that can change the model structure or modify parameters and information elements in relation to the new requirements that arise. However, MACRAME has mainly been used (through its implementation in Microsoft ACCESS) as a methodology to support an analyst's activities in a project, according to the original purpose of the methodology.

In the past few years, the Representation Network, the cognitive mapping tool of MACRAME, which is activated by the Problem Formulation function, has become very useful in situations in which the main issue is the need to interview people whose knowledge, in

relation to a decision problem, is relevant within a decision process. Acquired knowledge elements can be confused, contradictory or equivocal and MACRAME activates sequential steps in which the actors' representations are structured by the Representation Network and are then critically analysed and restructured with the decision makers and/or the involved actors until a global representation of the problem is accepted.

MACRAME and, above all, its cognitive mapping tool have been used in a conceptual design context to identify and analyse the requirements of all the possible users of Unmanned Aerial Vehicles for civil use (Norese *et al*, 2012). It has also been used to support a multi-unit project team in order to elaborate a shared vision of the main uncertainties and complexities, adopting a structured and evolving Problem Formulation, and to coordinate the overall action of the project team and orient it in a context in which the specialized competency of each unit had made the coordination, communication and decision making very difficult (Norese, 2011).

The main critical issue of these applications was the difficult communication between actors. The structured maps, which can synthesize and easily visualize all the knowledge elements, have been useful in decision contexts that imply quick (and sometimes wrong) decisions, but also involve a critical revision of previous decisions.

In the case under examination, some tests were developed and oriented towards improving the development of cognitive maps and their use in relation to the different functions of MACRAME. The result is a set of instructions that can be used to better apply and integrate the cognitive mapping approach in MACRAME, with the aim of elaborating an 'automatic' application of the Representation Network in the future.

A cognitive map can be used to construct and accumulate knowledge, allowing the 'mind's eye' to visualize images and physical paths, but also the structure that links concepts in terms of specific relationships, such as causality, influence, explanation, complement, contradiction and so on. A cognitive mapping approach is used to acquire and model beliefs and values, and this is an easy way of representing the point of view of different actors. A map can be used as an explicit basis for negotiation, between the problem helper and his client, concerning the content and structure of his problem or to understand the situation and to represent it to the involved actors (Eden & Huxham, 2001).

Different cognitive mapping approaches have been proposed in the literature. These range from causally chained networks such as those of Vennix & Gubbels (1992) to relevance diagrams such as the knowledge maps proposed by Howard (1989), or to a richer structure that includes consequences and explanations, for example, the cognitive mapping by Eden & Ackermann (2001) that has been applied several times in recent years (see, e.g., Eden, 2004 and Johnson & Lipp, 2007).

The Representation Network is a cognitive mapping procedure that is used, together with other MACRAME tools, to structure acquired knowledge and use it in order to formulate and structure the problem. Networks, in which nodes indicate concepts and proposing sources and arcs denote relationships between concepts, structurally represent specific elements of the analysed problem through key concepts that the interviewees considered during a previous phase of the decision process or that are discussed together with the analyst.

The Representation Network procedure has been applied to the considered case study to identify and analyse specific problem elements in order to better orient the investigation and analysis, then to activate other MACRAME functions and finally transfer knowledge elements to the decision makers of the IV faculty of engineering at the Politecnico di Torino.

Operational approach during the interview procedure

There are about 900 engineering students at the IV faculty of the Politecnico in the Bachelor degree course and 300 in the Master degree programme, and each of them completes a questionnaire at the end of each course in order to evaluate the perceived quality of the course and the lecturer. A set of free interviews was considered more useful than a specific new questionnaire to obtain more detailed and validated opinions of the new formative supply, in order to analyse and represent the 'elements' of the students' perception.

The choice of the best way of interacting with students is very important in order to allow the analyst and the decision makers to acquire a global and, at the same time, specific vision of the situation. The path the authors adopted started from an analysis of the uncertainties that can characterize the operational approach. This resulted in some methodological questions in relation to the investigation: how many and which students should be interviewed, who would the interviewers be and what should their attitude be in relation to the interviewees and the procedure they had to follow, how to guarantee the validity of this knowledge acquisition process, and, finally, how to synthesize, validate and use the results of the interviews. A need to cover the different specialization disciplines of the faculty and all the years of the faculty programme was recognized, but it was decided to choose students at the start of the second year as the youngest students, as a first, almost clear perception of the situation had already been acquired. The inclusion in the sample of some students who were known, for example, for their activities in research groups, laboratories or stages was considered an important opportunity to guarantee an easier testing of the approach at the start of the investigation and, at the same time, it was considered important to include 'good' and 'not-so-good' students in terms of their exam marks and, above all, students who were clearly critical about the organization and others more oriented towards 'supporting' the organization through proposals or suggestions. It was also decided to include three

students, who were involved in the Faculty council and in some commissions, in the investigation. Their opinion was considered important because they somehow play an active role in the organization and they should be more aware of the main critical elements than other students because of their institutional role.

Two students who were at the end of their Master of Science programme were chosen to be the interviewers because of their proximity to the interviewees in terms of age and knowledge of context; they participated in the investigation during their thesis project. An oral interview, without a tape recorder, but with written contextual notes of the interview and subsequent transcription as well as validation by the interviewed students, was chosen for two main reasons. First, human contact creates a friendly environment in which the interviewees can express their opinions freely. Second, the choice was driven by the need to be able to adapt the set of questions to the attitude of the students in order to widen specific aspects of interest and leave the interviewees free to give more details. The first interview lasted up to 1 hour, and 1 hour therefore became the average time of each interview.

If this approach is adopted, the set of interviews has to offer a complete representation of the situation, but at the same time the number of the interviews has to be minimized. The vision of the problem has to be analysed, structured and transformed into possible decisions and actions, which should be implemented as soon as possible. In order to keep this number to a minimum, each new interview has to be analysed not only to acquire knowledge but also:

- to check whether some new elements have been proposed and
- to identify any actual or apparent contradictions between views, which can be used to verify the reliability of the sources or to identify specific aspects requiring attention and new interviews.

The number of interviews was not defined *a priori* and, at the end of the analysis, 30 students attending different years of the bachelor course and the Master of Science programme, plus the three representatives, were interviewed. The interviews were carried out both in spring, during the second semester courses and before the summer session exams, and in autumn, at the start of the first semester courses. The interviews were interrupted when each new interviewee was not able to give any more details or to propose new or contrasting opinions. Two key aspects were taken into account to stop the interviews: first, when all the different kinds of students (bachelor, master, of different years) were interviewed; second, when the new interviewees were not able to add new key elements to the already acquired knowledge or to contradict what had been declared by other students. In other words, the interviews were stopped when a sort of 'logical convergence' of knowledge elements emerged. It was also proposed to repeat the interview process after some years in order to guarantee a link between the faculty and students and to confirm or modify the vision that resulted from the previous application.

In order to obtain a potentially useful result, a 'cyclical' model, which consisted of six steps, was adopted to conduct and validate the interviews.

Step 1 Generation of a first draft. Although the oral interviews were conducted in a free manner, a first draft of the main 'questions' was drawn up, in order to have a path to follow, a track to keep the discussion open and to hold the attention of the students, at least in the first, more difficult interviews. It was decided to prepare a list of questions that would be neither too specific nor too general, based on the informative needs of the faculty and which were compatible with the aim of taking into due account any topic proposed by the students.

Step 2 Interviewing some known or well-known students to test the proposed list of questions and the communication environment in order to have a first feedback on the clarity of the requests. A central aspect in this phase was to avoid ambiguity in both the questions and answers. A secondary aim was to identify any important topics different from those considered in the draft 'questions'.

Step 3 Analysis of the test interviews in order to improve the draft.

Step 4 Interview and transcription of the interview in a written text, to be sent back to the interviewees, in order to be validated or integrated/changed.

Step 5 Verification of the reliability of some specific indications of students (in some cases the problem they described was the result of a misunderstanding or a too personal interpretation of a regulation).

Step 6 Validation of the transcribed interview via send-back to the respondent. In some cases, more details and/or clarifications were explicitly requested. In this case, it was possible to interview some students again, but unfortunately this is not always possible.

The procedure was characterized by two main cycles, the first in relation to the draft and its improvements, and the second pertaining to Steps 4, 5 and 6, which were carried out concurrently with new interviews. This means that while interacting with some students a simultaneous verification and validation of the already conducted interviews was being made. This was done in order to have constant feedback on the validity of the interpretation of what the interviewee had said in order to be able to verify any 'unexpected or strange' indications by the students in the remaining interviews.

Interview analysis by means of the Representation Network methodology

An analysis has to extract and use the ideas of each and every interviewee. 'It must be able to contrast and compare views, without being judgemental, and to combine apparently conflicting views in terms of sub-problems

requiring attention' (Bowen, 1994). The proposed methodology begins with the analysis of each validated interview and its organization in statements and information cells. A single interview is not sufficient to understand what the structure of the acquired knowledge is. The knowledge structure 'is not pre-planned, but it has to be determined, as a convenient set of categories, by the material itself' (Bowen, 1994). The structure starts to become evident when some interviews are analysed and their components coded, but it can only be stabilized when all the interviews are made, transcripted, validated and analysed.

Therefore, the first analysis is focused on a specific interview, and then the step from one interview to the others allows the analyst to identify a possible structure of themes (or topics or subjects) that, in some cases, are intentionally discussed during the interview, but could freely emerge without the specific intention of the interviewer. When all the acquired elements have been synthesized in concepts and clustered around a key element, identification and analysis of the relationships between concepts generate a logical map, a representation network (RN) that can reconstruct opinions and points of view and represent them systematically and with a consistent level of detail.

A structured reading of this map, and above all of its capability to underline categories of problems that have to be faced and uncertainties that have to be controlled, informs and orients decision processes. The procedural elements of the Representation Network methodology are: organization of each interview in information cells, synthesis of the interviews in clusters of concepts and creation of the RNs. The activities that should be developed in each element of the proposed procedure are described in detail hereafter.

Organization of each interview in information cells

(1) *Statement structuring*: The analysis of a single interview includes its structuring, in statements, and the analysis and coding of each statement in information cells. The transcribed and validated text of the interview has to be divided into statements that basically correspond to the different sentences of the interview. If the interviewee has expressed his/her opinion about a specific theme at different moments of the interview, the related statements have to be transcribed in sequence.
(2) *Statement labelling*: Each statement has to be labelled in relation to its nature (criticism, wish, suggestion, aspiration, aim, judgement, expression of preference and so on) and to the related theme or subject (which, in this case, can be documentation adequacy, students' guide, teaching material etc.) if it is sufficiently clear. At this point, the statement is transformed into an information cell.

When the number of the analysed interviews grows, the identification of the themes becomes easier because a new interview can clearly suggest a theme that was present in some previously analysed interviews, but which was not sufficiently clear to have been recognized as a theme. Finally, when all the interviews have been analysed, all the statements can also be labelled in relation to the related theme.

Synthesis of the interviews in clusters of concepts

When the set of interviews has been organized, all the statements of the different interviews can be analysed together in relation to the treated theme/topic in order to synthesize statements and information cells into concepts and create clusters of concepts.

(1) *Topic evidencing*: All the statements that are related to a specific theme are included in a list, with the information pertaining to the nature of the statement and the name of the proponent source. A different list can be created if the topic that has to be evidenced is a specific kind of statement (such as a criticism or a suggestion).
(2) *Concept identification:* The central concept that is expressed for each listed and coded statement has to be identified in order to synthesize the statement with a few words. If a statement seems to express more than one concept, it is possible that the previous structuring results need to be re-analysed and the statement divided into two or more different statements. A second possibility is that the real meaning of the sentence in the interview was not sufficiently clear and the equivocal interpretation is a sign of this uncertainty. An explicit request for clarification from an interviewee is very useful in some cases. If several statements express, with partially different words, the exact same concept, only one version should be used, without changing the meaning and indicating all the proponent sources. Moreover, if some concepts present only marginal differences, these have to be underlined and analysed, if possible, while interacting with the proponents, to understand the meaning of the differences and then reduce these concepts or leave them as they are.

Generation and analysis of the RNs

At this point, the statements from the interviews are organized and synthesized in concept clusters, which are related to specific themes and labelled in terms of nature of the concept and proponent source(s). In some cases, the clusters can be elaborated in relation to the kind of concept or to a group of proponents.

Each cluster can generate a cognitive map, which is called RN in this methodology, if semantic links between concepts are identified and represented as labelled arcs that connect the concept nodes. The nature of these links can be different, but if a link underlines a contradiction this has to be identified and analysed.

(1) *Concept connection*: The logical relationships between the concepts of a cluster have to be identified to create a cognitive map, that is, a network that

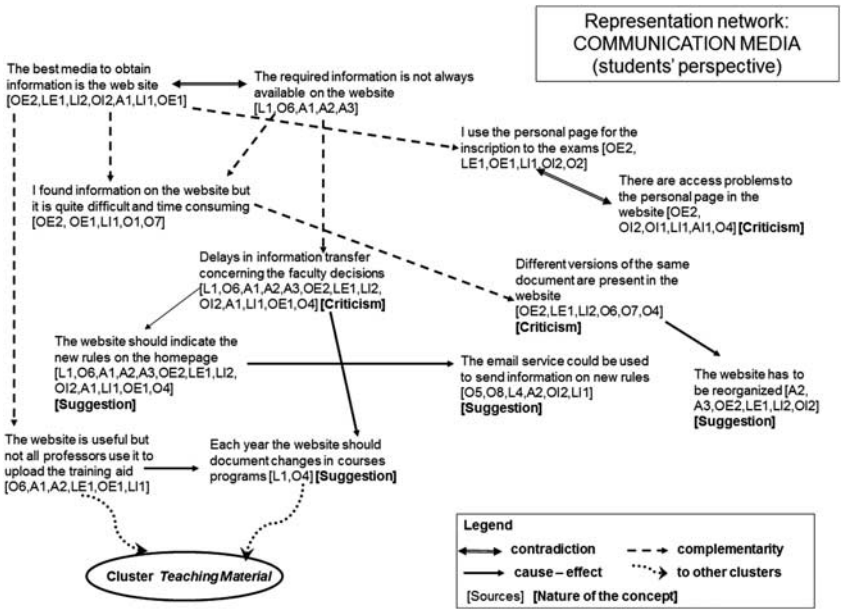

Figure 1 An example of RN.

represents and synthesizes the knowledge elements that the concepts and their proponent sources propose. Different relationships can be identified:

- Explication, cause and effect, exemplification, exception, condition;
- Equivalence, complementarity, inclusion;
- Concordance, contradiction,
- ….

(1) *Contradiction identification and analysis*: Contradiction identification is crucial for logical reasoning and plays an important role in communication, understanding and learning (Medaglia *et al*, 2009). An apparent contradiction has to be analysed in depth and reduced or understood. When there is a possible contradiction between concepts (which are expressions of constraints, needs, temporal requirements and so on), a misunderstanding about the terminology could have arisen during the interview or during the first steps of the interview analysis. The cause of this misunderstanding has to be found and analysed with the interviewee or the previous work has to be checked. When the cause is not a misunderstanding, it is essential to clarify why the contradiction has arisen, to evaluate the reliability of a source or to identify specific aspects that are not clear enough and have to be analysed in the subsequent interviews or using other information media. Knowledge cannot consist of contradiction, but it may be acquired through contradiction in the sense that it is often through the discovery and subsequent removal of contradiction that knowledge is acquired (Agazzi, 1990).

Each RN facilitates visualization and structuring of the problem, which is desegregated into sub-problems and their specific components (one for each RN) that have to be analysed to produce the essential elements for a decision, or a new analysis, pertaining to how and where the actors (in this case the students) direct their attention. An example of RN is presented in Figure 1. All the concepts in relation to the media that support communication in a faculty are inserted in the network, keeping track of the source and in some cases of their specific nature. Some concepts are related to specific events or situations and have been previously verified. Others are opinions and the number (and in some networks also the role) of the proponents with the same opinion is informative. When the concepts are too generic, they can be completed and explained by other concepts concerning the same theme, if they are analysed together in a RN.

The relationships between concepts are defined in relation to the nature of the concepts (e.g., a *cause–effect* relation between a criticism and a suggestion) and with the aim of explaining the knowledge elements that the concepts propose. A *complementary* relation, between concepts but in some cases also between maps, facilitates the understanding of single concepts. The connections with another map (RN Teaching materials in this example) can make the comprehension of some described situations easier. *Contradictions* are identified and put in evidence in order to distinguish between an equivocal statement that has to be clarified, or a signal of real problems that have to be faced.

Results

The application of MACRAME to the fragmented knowledge obtained from the interviews has allowed a structured representation to be developed through the cognitive mapping approach, and a Multi-level Schema to be

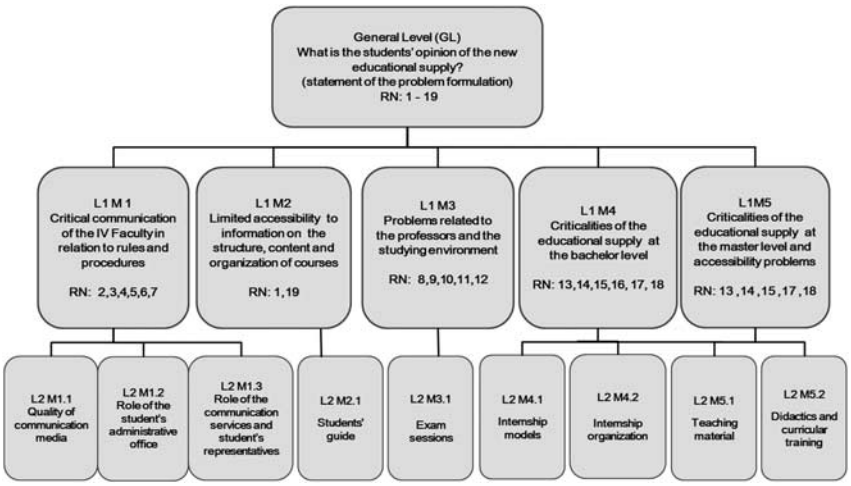

Figure 2 The MACRAME Multi-Level Schema.

elaborated. The Multi-level Schema, which is represented in Figure 2, breaks the problem down into modules and levels of growing specification and lower analysis complexity. At a specific level of problem structuring and modelling, the Schema orients and documents activities that control uncertainty and critical issues. Each module includes the knowledge elements pertaining to a specific 'component' of the problem by means of: Problem Formulation, which may be expressed by means of one or more of its possible structures (Statement of the Problem Description, Actor Structure Network, which represents the actor structure related to the level, and RNs), the Problem Dimensions and the Model Structuring Dimensions (or Model Dimensions).

A Problem Dimension refers to the main uncertain or critical elements of a specific sub-problem that is analysed in the module. All the Problem Dimensions of the Multi-level Schema have to be treated separately and then integrated in a global view. The Model Structuring Dimensions act like transition structures from a Problem Dimension to a problem treatment activity that is explicitly required, from one level to another, which is activated when it becomes necessary. Local formalized results can be obtained at almost all the different levels, but only at the last one can the global representation be formulated in relation to a sufficiently structured and therefore reduced complexity. All the elements in the decision problem model are explicitly shown and are related to sources and proponent sectors or actors. The view is global and its consistency can be tested because each knowledge element has to be read in relation to all the others, and each partial contradiction or uncertainty or incomplete analysis or treatment has to be dealt with.

The results of this MACRAME application are here described by the analysis of the Multi-level Schema modules. The different activities of knowledge transfer to the decision makers and their decisions are presented at the end of this section.

Output from MACRAME

The General Level (GL) of the Schema includes the point of departure of the structuring application, that is, the Problem Formulation at the GL. This is a first analysis structure, which includes the description of the problem and the faculty management group who generated the enquiry, the aims and the motivations of the adopted enquiry approach and the declaration of the 19 RNs that the enquiry identified. The keywords that were used to synthesize the theme of each RN are listed in Table 1, with the number of concepts and proposing sources of each map.

The Problem Dimensions arise from the Problem Formulation and above all from the analysis of the enquiry results obtained through the Representation Network methodology. The Problem Dimensions tool offers a clearer view of the problem, underlines their components and activates consistent dimensions of model structuring, with the ability to manage different aspects of a problem separately.

In this case, the first Problem Dimension at the GL is that the results of the enquiry underline an important difference between the initial Problem Formulation and the interview results: the students' point of view on the reorganized teaching programme was needed and stimulated by the interviewers, but other critical aspects arose.

The second Problem Dimension indicates that three kinds of sub-problem were identified, thanks to the 19 RNs: Difficult communication between faculty and students, above all concerning rules and new regulations; Organizational problems that were only in part the faculty's competence (but the interviewees were substantially unable to recognize the difference between faculty and university); Quality of the teaching programme.

Only the third sub-problem was initially perceived by the faculty head. The other two sub-problems were not perceived by the decision makers before the enquiry, but instead emerged during the analysis of the interviews.

Table 1 Representation networks with number of concepts and sources and identification code

RN	*Concepts*	*Sources*	*ID*
Students' guide	17	18	1
Communication services	8	11	2
Communication of new regulations and rules	11	19	3
Changes in regulations and rules	3	7	4
Students' administration office	12	9	5
Communication media (students' points of view)	12	13	6
Communication media (student representatives' points of view)	8	3	7
Study environment	8	7	8
Exam sessions	6	12	9
Professors	4	10	10
M.Sc. enrolment	7	4	11
Roles of the student's representatives	8	3	12
Teaching material	10	13	13
Structure of the courses	11	2	14
Organization of the courses (students' points of view)	10	11	15
Curricular internship satisfaction	11	10	16
Curricular internship organization	10	11	17
Changes in the courses	9	9	18
Organization of the courses (student representatives' points of view)	9	3	19

The problem of difficult communication, which is described by six RNs that include 54 concepts, presents different aspects and is almost as rich in implications as Quality of the teaching programme. Organization problems that are only in part the faculty's competence are described by two RNs that include 26 concepts. Overall, 11 RNs, which include 94 concepts, describe issues pertaining to Quality of the teaching programme and aspects that could be improved.

Only one model structuring dimension acts at the GL and activates a new level of analysis with two modules, for the sub-problems Communication (L1M1) and Organization (L1M2), and three modules to deal with the sub-problem Quality of the education supply (L1M3, L1M4 and L1M5) (see Figure 2).

The three Problem Dimensions or critical elements of the L1M1 module are: students' limited use of the available communication tools; the need for well-timed communication between the faculty and students; the need for effective communication between the faculty and students.

Two Model-Structuring Dimensions are proposed from the L1M1 module. They act like transition structures from a problem to a problem treatment activity, from one part of the schema to another and from one level to another. The first structuring dimension states that a text with all the different suggestions and proposals that could improve the communication processes has to be elaborated and addressed to the decision makers (with a clear distinction between the two kinds of proposal source, the students or the technical analysis that MACRAME orients and documents). In relation to the second structuring dimension, a new level has to be activated for the specific treatment of the three following aspects: Quality of the communication media, above all the Faculty and the Politecnico Websites (L2M1.1); Role of the student's administration office in the communication processes (L2M1.2); and Role of the communication services and the student's representatives in these processes (L2M1.3).

The modules at the second level (L2) (the last, in this case) present the same components: Problem Formulation, Problem Dimensions and Model Structuring Dimensions. The structuring dimensions activate different paths in order to transform specific knowledge elements from the students into operational frameworks to be communicated to the organizational structures in charge of the respective subjects. The L2M1.1 module describes the main problems of the Websites that were indicated by the students and verified through a direct investigation, and proposes a list of suggestions to improve the situation. L2M1.2 describes the main critical situations that arose because the students' administration office gave the wrong answers to the student's questions, and tries to explain this phenomenon through three Problem Dimensions: involvement of young collaborators with a limited knowledge of the regulations, ill-timed change communication from the faculty to the office and misuse of the notice boards. The need to improve the relationship between the faculty and students' administration office is underlined by the structuring dimension of the module. L2M1.3 (through four RNs) analyses the main criticisms of the faculty and its teaching staff concerning their communication procedures. At the same time, it underlines the essential role of the students' representatives as a communication resource and suggests their involvement in the improvement of the communication services.

The other modules, at the first and the second level, present a specific reading of each sub-problem and offer some suggestions. L1M2 describes how and why students

misuse information on the courses and their role in the learning process, and L2M2.1 stresses the need to change at least two specific sections of the students' guide.

L2M3.1 offers some suggestions about a new organization of the exam sessions, the only actual improvement of the study environment that L1M3 describes in terms of psychological and relational Problem Dimensions.

The three modules L2M4.1, L2M4.2 and L2M5.1, at the second level, deal with the operational aspects that are generated from the critical issues of the teaching programme and present improvements in the nature and organization of the internship and teaching material. L1M5 and the last module, L2M5.2, underline the problems of the actual accessibility to the Master level in terms of required basic knowledge and competencies, and offer the following suggestions: a tutoring service as already exists in another faculty of the same university; a more detailed analysis to understand the specific competencies that have to be acquired before each course of the master level; the analysis of a possible revision of the admission regulation for the students who arrive from other engineering faculties.

Knowledge transfer to the faculty management group

A document that synthesized all the elements that MACRAME structured was sent to the faculty head and to the students' representatives.

The students' positions in relation to courses, teaching material and internship (which the Bologna Process has included for the first time in their course programme) were synthesized in a text, which included the complete and explicit definition of the concepts the Representation Network procedure had structured. This document was sent to the two members of the faculty management group in charge of the Bachelor degree course and the Master of Science programme.

A different path was followed for the unexpected and critical aspects that arose in relation to communication. The faculty head was gradually informed of this particular issue during the enquiry process and, only at the end, the related documentation (with the results of specific analyses in loco and verifications that some RNs had required) was also sent to the member of the faculty management group in charge of the Communication commission.

The 'organization problems that are in part not the faculty's competence' were analysed through MACRAME using the RNs that propose these issues. The results were synthesized in a document that underlined the difficult understanding (not only for the students) of the different roles, competences and resources of a university and a faculty and suggested a better cognitive involvement of the students in relation to this theme (e.g., through presentation of the Politecnico on the website or a pictorial description of the organizational structure to be used in the course syllabus or when the university and their faculties are presented to high-school students).

These proposals were discussed by the faculty group that is responsible for the change process, and some decisions were made about the internship organization, the students' guide and the involvement of the students' representatives in order to obtain a better communication of the new regulations to the students. More attention to the relationship between the faculty and the students' administrative office and, above all, a new trend that eliminated continuous changes were implemented. The Communication commission and the faculty website (indicated by most students as the most frequently used media source, but also the most confusing) were reorganized. The website reorganization above all concerned the reconstruction of web pages, with easy access to regulations and curricular training information, which had been pointed out by the students as being crucial issues, and the insertion of a specific section with proposals for thesis projects and work periods and the possibility of highlighting new regulations. A young assistant professor was involved in the Communication commission and was given the task of coordinating the reorganization of the website and verifying the coherence of the uploaded information.

No clear description of the university or of its organizational nature and complexity has been presented to the students until now. The organizational nature of the Politecnico is at present undergoing an extensive change. This could be a good occasion to describe the new organization to the students.

Conclusions

A decision of the head of an engineering faculty has led to an enquiry to acquire an organizational view, from the students' point of view, about the change issues the 'Bologna Process' has introduced into the faculty. A problem structuring methodology, MACRAME and, above all, its cognitive tool, the Representation Network have been used to obtain and use knowledge elements from interviews, in order to support the decision structure of the faculty.

The cognitive mapping procedure helped to integrate the multiple perspectives and several knowledge 'fragments' in a clear and structured Problem Formulation and, above all, to allow the decision makers to understand and share some new problems that had not been perceived beforehand. The interviews were structured using a procedure that logically and visually synthesized the students' points of view in cognitive maps. The use of MACRAME then led to the identification of three main critical areas of issues, to the understanding, through specific modules, of their multi-dimensional nature and to the proposal of organizational procedure improvement and, above all, of communication activation.

A simple and transparent methodology that can facilitate decision and communication has been made available to the organization to support the intelligence phase of the decision process and to easily synthesize a structured and validated representation of the students'

points of view in tables and cognitive maps, but also in analytical models. The creation of 'objects' like these tables and cognitive maps, which can be considered an interface between 'soft' and 'hard' methodologies, can constitute a means of acquiring and sharing new ideas, in relation to people who are not involved in the decision process but who can propose essential perspectives of knowledge to the decision process.

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