Graphic knowledge representation as a tool for fostering knowledge flow in informal learning processes

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Abstract

Graphic representations are a thoroughgoing communication language. Their development has received considerable impetus from the field of artificial intelligence and more generally from all those areas which have attempted to “capture” knowledge domains in “digital mode”. They are formally represented so that they can be used by specific software engines, e.g. intelligent systems, decision support systems, semantic webs and simulation systems.

Thanks to their simplicity and effectiveness, some of these graphic languages have spread beyond the specific area from which they originated, to other areas where their use has often been further simplified and made less rigorous, so that even non-specialists have been able to capitalise on the basic concepts.

The question is: when are these graphic representations useful for the professional communities in fostering horizontal knowledge flow in informal learning processes?

This chapter discusses the results of an experimentation with graphic approaches to knowledge representation during informal learning processes based on problem-solving in the healthcare sector. The tools chosen for the experimentation were conceptual mapping and Petri Nets, developed collaboratively online with the aid of the CMapTool and WoPeD graphic applications.

Our specific aim was to analyse and discuss their real usability and effectiveness in fostering collaborative interaction, knowledge sharing and information exchange during a process designed to study a specific professional problem.

INTRODUCTION

When we speak of technology-mediated social interaction we are often referring to resources such as forums, wikis, social networks etc. However, other equally effective tools for fostering dialogue, collaboration and "knowledge maturing"(Kaschig et al., 2010) within professional communities should not be neglected.

These include the technologies for graphic representation, which have often shown their versatility in illustrating concepts, processes and other forms of knowledge (Donald 1987; Trentin, 1991; 2007; Olimpo, 2011).

Graphic representations facilitate alignment of the participants' varying conceptual images, helping reduce what is often defined as "semantic noise" (Shannon & Weaver, 1949), i.e. the different ways of understanding a word, a sentence, a concept, especially when communication is limited to the verbal, and that mostly in an indirect form like computer mediated communication (CMC). We should in fact not forget that knowledge flows are markedly affected by the context in which they are developed (school, company, amateur associations, etc.) and by the features of the users (age, education, culture, professional skills, etc.).

It is no coincidence that, in a discussion group, oral explanation of the speaker's viewpoint is often accompanied by simple diagrams drawn on the spot either on paper or on a board. The speaker thus provides a conceptual image (van Lambalgen & Hamm 2001; Stokhof 2002; Wheeler 2006) of the portion of knowledge to be discussed. This in turn triggers a process involving explicit, implicit and tacit knowledge (Polanyi 1975; Nonaka & Takeuchi 1995).

The same thing also often occurs during interaction among members of an online professional community. In this case though, instead of paper or boards, *ad hoc* graphic editors are used. These allow online circulation of graphic representations as a support for collaborative interaction.

This chapter will particularly refer to two specific methods for the graphic representation of knowledge, Concept Maps and Petri Nets, and related software applications.

Both these representations have already been examined in depth in the previous chapter (Olimpo, 2011). We will illustrate here their practical application in stimulating informal learning processes within specific professional health sector communities.

RESEARCH ISSUE

One of the main aims of the research has been to experiment the use of graphic approaches to professional knowledge representation. We wished in particular to analyse and discuss their actual usability and effectiveness in fostering collaborative interaction, information and knowledge sharing during a process for the investigation of a specific professional issue/problem.

The participants and the task assigned to them

Two distinct professional communities have been involved in the research. The first (Audit community) was made up 33 head physicians and health care managers pertaining to Local Health Unit 11 of Livorno (Tuscany Region) who had the task of dealing with the theme of Clinical Audit, the key elements characterising it and the working methods to carry it out. The second (Alert community) formed by 18 technical staff from the Department of Nutrition and Food Hygiene coming from all the health care units in Tuscany. In their case, the task was to define the organisation of a Regional Working Group on the problem of managing food alerts.

To carry out their task, the members of the two communities could count on both handbooks and the specialised documentation of the sector, as well as on the sharing of knowledge and experience which the members of each community (with their various roles within the Local Health Authorities, ASLs) had acquired on the specific topic.

The two communities were asked to collaboratively develop, as the final product of their work, a sort of online handbook on clinical auditing and food alert management, respectively. The handbook had to be in a form which could be (a) easily added to and updated and (b) had to offer a structured presentation of information acquired through consultation of the specialist documentation and through the sharing of experiences and practices inside each community.

For the planning and development of the online handbook, integrated use was made of conceptual maps and wikis. To be specific:

- maps were used to support the horizontal knowledge flows within each community, thus fostering the process of convergence towards a shared network structure of the artifact;
- wikis were used for collaborative online implementation of the artifact (i.e. the handbook on the assigned theme); wikis were proposed because we wished to create an artifact which could be easily added to and updated beyond the first version developed during the experimentation.

The collaborative strategy

For the collaborative interaction in the development of the artifact a mixed strategy was proposed: shared mind and division of labour (Diaper & Sanger, 1993).

The *shared mind* strategy, in which all the community members work on each single part of the artifact, was applied (a) in the definition stage of the wiki structure (with the aid of graphic representations) and (b) in its final revision, in which each member intervened on other cowriters' pages suggesting modifications, integrations, new hypertextual links, etc.

The *division of labour* strategy was instead applied at the stage of the actual writing of the wikis, where a specific topic for development was assigned to every community member on the basis of his/her previous experience on this topic (technical, administrative or clinical, according to their specific roles in the Local Health Authority, ASL). In any case, participants had the chance of inspecting what was being developed in the other sections of the wiki at any moment, in order to create hypertextual links with their own part of the document.

In the continuation of this chapter we will be examining the part of the collaboration which applied the shared mind strategy. This was supported by formal graphic languages which fostered dialogue and the sharing of the community members' various conceptual images regarding the topic to be studied.

For the part concerning wiki development, we refer the reader to another publication (Trentin, 2011), which also addresses the problems linked to assessment of single community members' degrees of contribution in the overall development of the online handbook.

Operating methods

Going back to the first part of the study, i.e. to the definition of a shared conceptual structure of the wiki, as already mentioned, concept maps and Petri Nets were proposed to both communities as methods for graphic representation of knowledge. The development of each graphic representation was divided into three stages (Trentin, 2007):

- a face-to-face meeting for preliminary familiarisation with the graphic approach and related editing software;
- two weeks of collaborative online activities in sub-groups;
- a final meeting to evaluate and compare the graphic representations produced, and to discuss the collaborative online process implemented to produce them.

The participants were divided into sub-groups of 5-6 units and were asked to structure their work into two one-week periods:

- individual drawing up of one's draft of the graphic representation;
- sharing of graphic representation and convergence towards one single sub-group version of it.

To co-construct the two representations the following applications have been used:

- CMapTool (http://cmap.ihmc.us/) and WoPeD (Workflow Petri Net Designer) (http://www.woped.org/) respectively for the development of concept maps and Petri Nets;
- Moodle as environment to run interpersonal group communication.

THE GRAPHIC REPRESENTATIONS PROPOSED IN THE EXPERIMENT

Graphic representations are de facto a language of communication and, like any language, syntactic rules are needed for it to act as a medium in communication between two or more individuals (Donald, 1987).

Hence, specific graphic languages have been defined and formalised that are geared towards knowledge representation (hierarchical representations, semantic networks, concept maps, approaches to the representation of procedural knowledge, etc.).

Thanks to their simplicity and effectiveness, some of these graphic languages later spread beyond the specific area from which they originated where their use was often more simplified and less rigorous (Trentin, 1991), so that even non-specialists could capitalise on the basic concepts.

The question is: when are these graphic representations useful for the professional communities?

A first consideration regards their effectiveness in facilitating the multi-perspective study of a given knowledge domain and/or area of exploration: a new knowledge, the solution to a problem, the functionalities of a complex system. The representation of concepts through graphics amplifies, in the eyes of the interlocutors, the existence of multiple interpretations of one subject of study or debate (Cunningham, 1991).

A second consideration concerns the community's need for technological aids to improve the flow and organisation of community knowledge (Shipman, 1993; Prusak, 1994; Haldin-Herrgard, 2000).

We are aware the knowledge sharing processes (theoretical and procedural) are favored by two types of technological support: one for interpersonal communication and the other for the collection and management of information and knowledge (Auger et al., 2001). Both cases need to give a conceptual schematic representation of the knowledge domain of reference (or portions of it) for a given community.

Graphic representations can give an inside view of the conceptual interconnections between elements making up the knowledge that is being discussed and shared. It is therefore an effective way to facilitate the communication of conceptual images as well as the semantic organisation of informative, documentary and factual material contained in the community memory (Lave & Wenger, 1991). This last aspect is particularly interesting as many research engines now use conceptual representations of the knowledge domain in which they work for the selective recovery of information[1].

Before dealing with the experimentation which is the subject of this chapter, details of the two underlying representation tools of knowledge are resumed here below.

Concept maps

A concept map is a coherent visual logical representation of knowledge on a specific topic which encourages individuals to direct, analyse and expand their analytical skills (Novak & Wandersee, 1991; Halimi, 2006).

The approach was developed by J.D. Novak (1991) based on Ausubel's theories (1963; 1968) and Quillam's studies on semantic networks (1968). Concept maps use diagram representations which highlight meaningful relationships between concepts in the form of *propositions,* also called *semantic units,* or *units of meaning*. A proposition is the statement represented by a relationship connecting two concepts.

Therefore, there are two basic features used to construct concept maps: *concepts* and their *relationships* (Figure 6.1).

1. For example http://www.webbrain.com.

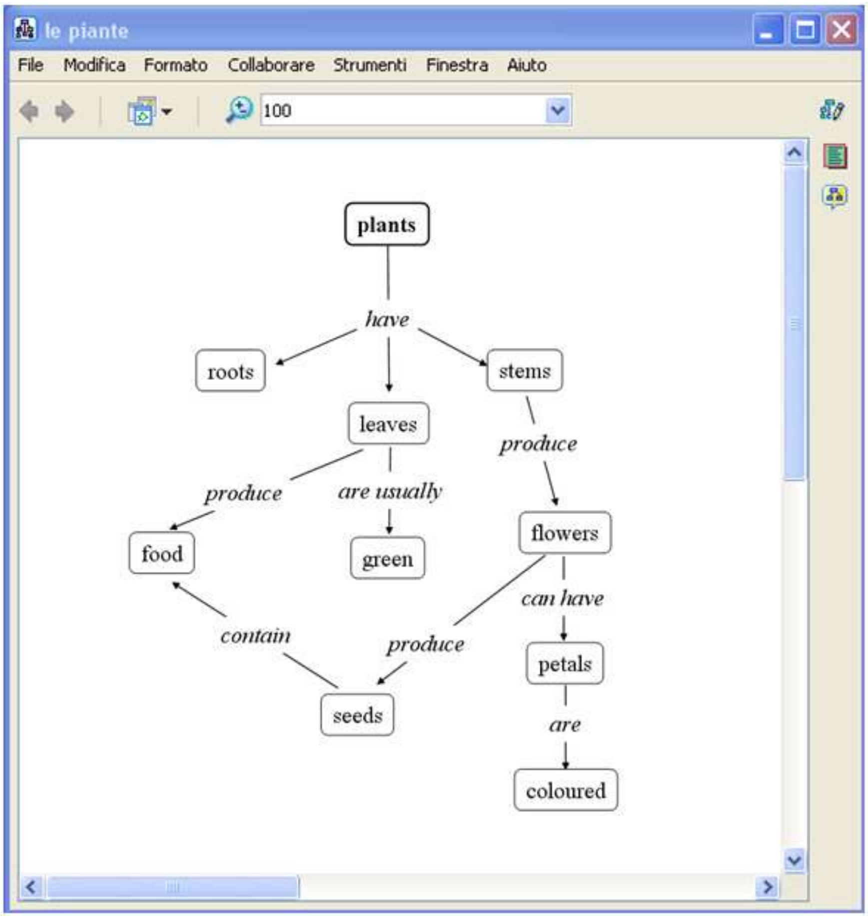

Figure 6.1 – Example of a concept map drawn with CMapTool

Besides the two basic features, a concept map is then characterised by hierarchical relationships between concepts and by cross-links between concepts belonging to different domains of the same map.

Various graphic tools for editing concept maps have been developed and the dialogue window in Figure 6.1 shows of one of the best-known: CMapTool. Many of these environments are able to link the different concepts to a variety of items (documents, images, films, URLs, other concept maps) with the possibility then of converting them into HTML format, thereby creating structured repositories that can be accessed online. This, for example, is one of the possible ways to organise an online community's shared memory.

Designing concept maps with these software applications is very simple and here, for example, is how one can work with CmapTool:

- after opening a new map and double clicking on the white area, the starting concept may be defined (Figure 6.2a);

- by clicking and dragging the arrow one can create a link between a new concept and the starting concept (Figure 6.2b);

- then the two concepts and the relation type linking them are specified (Figure 6.2c).

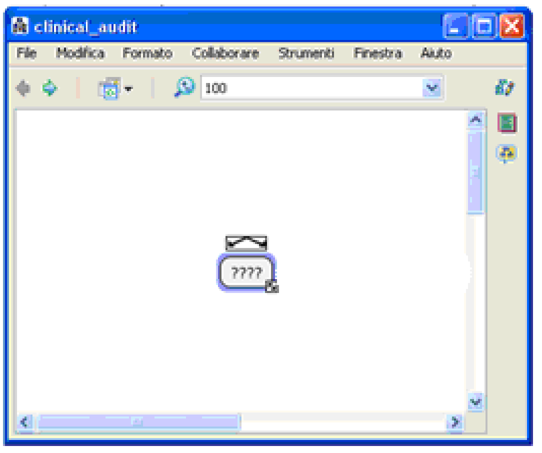

Figure 6.2a –The starting concept

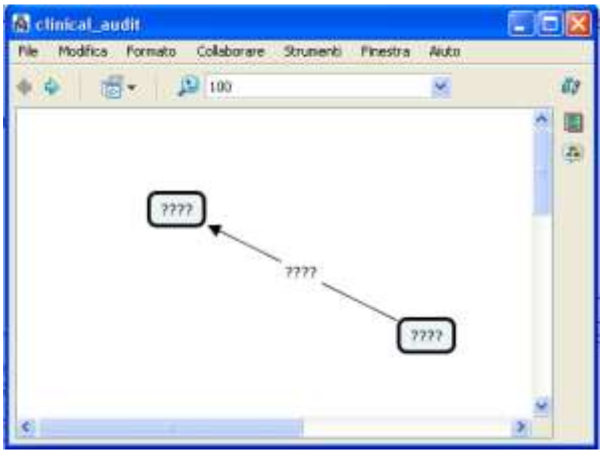

Figure 6.2b – The link between two concepts

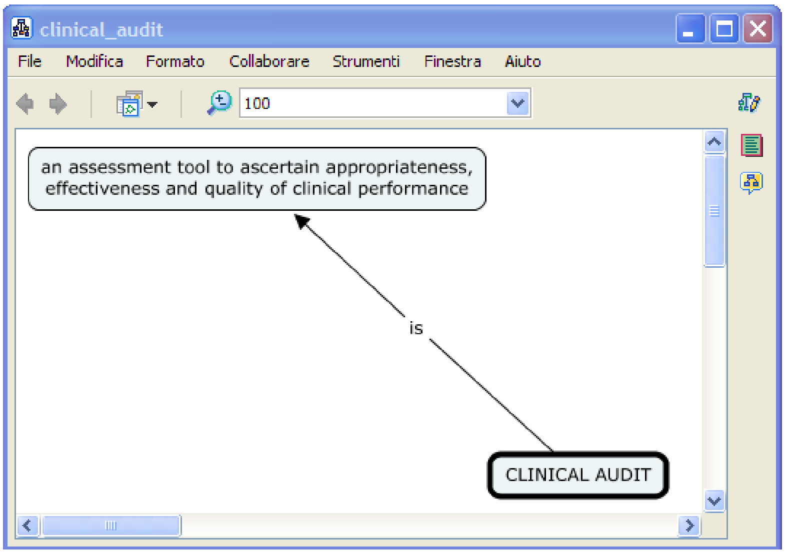

Figure 6.2c – Description of concepts and relation types

By proceeding in such a way, one can obtain graphic representations like the one reported in Figure 6.3 showing one of the maps produced by the Audit community during the experimentation described here.

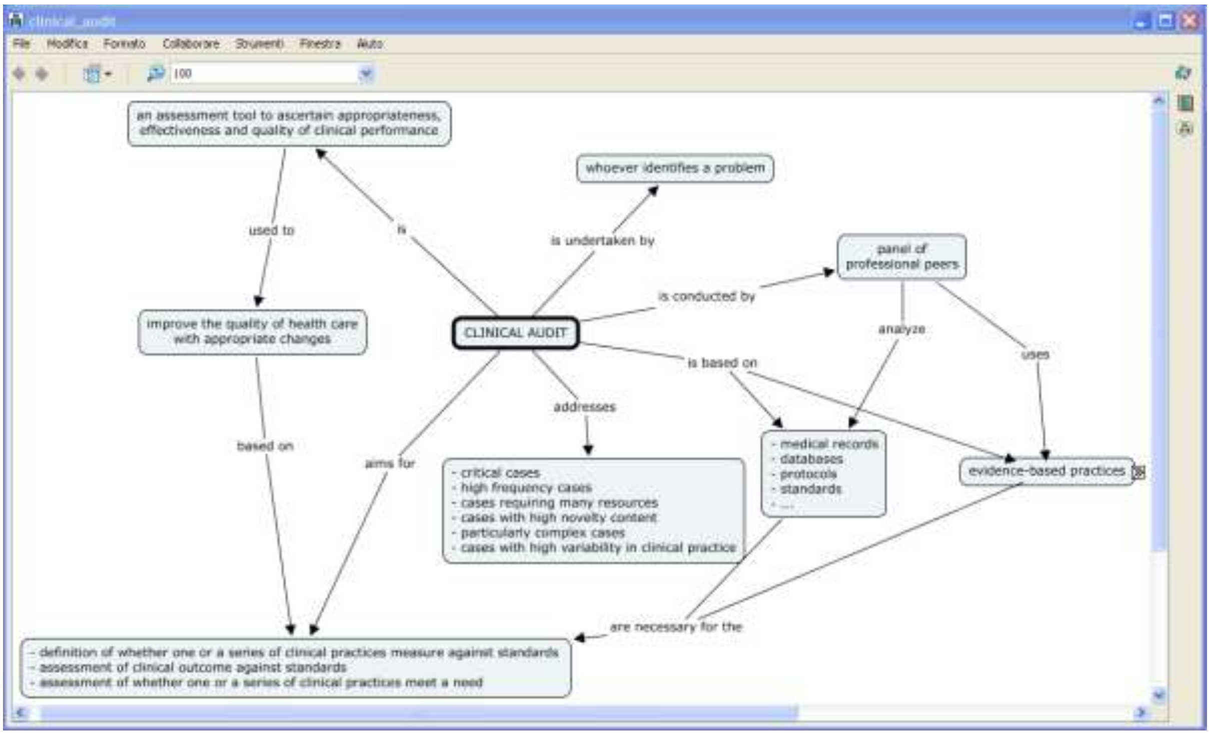

Figure 6.3 – A concept map on the clinical audit developed with CMapTool

When very complex knowledge domains have to be described, such as the clinical audit in Figure 6.3, the corresponding concept maps tend to become much larger and difficult to manage.

For this reason, CMapTools provide a function to compress/explode sections of the map being drawn.

For example, by clicking on the symbol “>>” that appears to the right of “evidence-based practice”, the map linked to that concept expands (see Figure 6.4). Then clicking on the symbol “<<” will take you back to Figure 6.3.

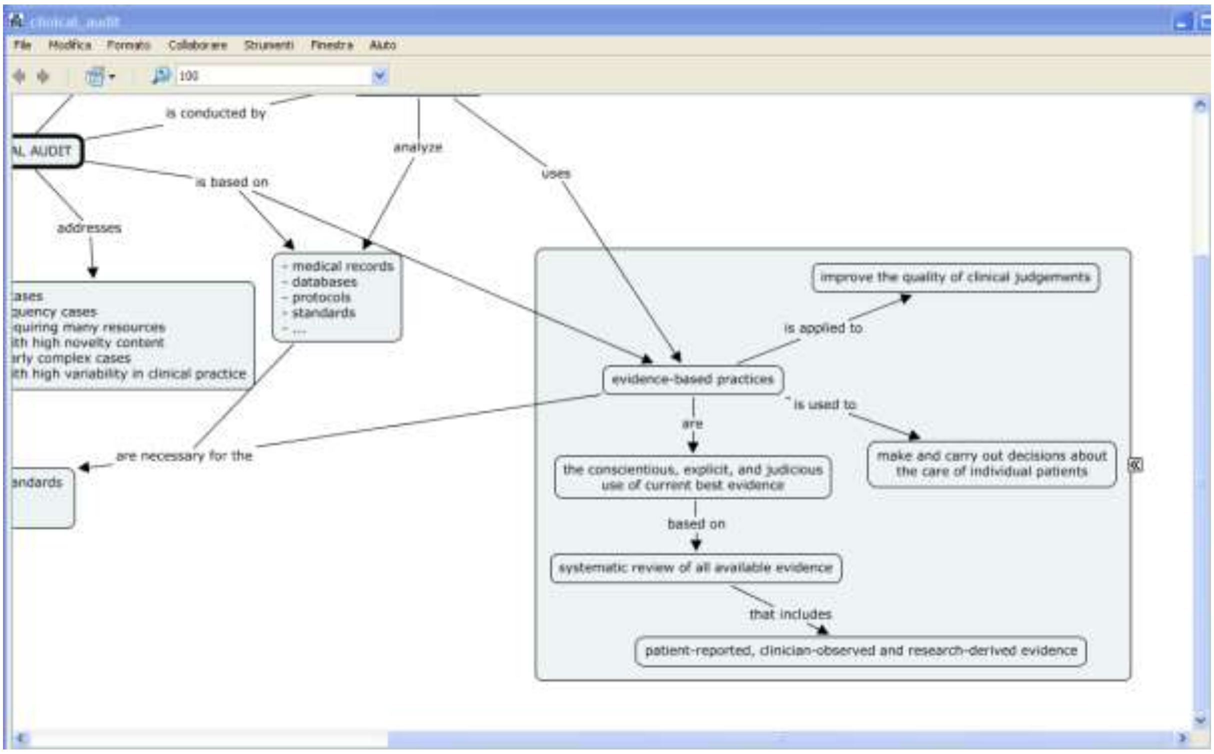

Figure 6.4 – Example of a complex concept expansion

Petri Nets and procedural knowledge representation

Petri Nets (PNs) provide an effective way to describe and analyse models, whether complex systems, processes, knowledge domains, etc. (Peterson, 1981).

On account of this characteristic, they are often used in the graphic representation of procedural knowledge.

PNs were also discussed in the previous chapter. Below, we recall their most important features and offer an extension of them (e.g. introduction of “successive refinements” or “top-down expansion”), as well as an example of their application taken from the task assigned to the Audit community.

Resources and activities

In the previous chapter (Olimpo, 2011), a PN was described as an oriented graphic in which two node types are represented (Figure 6.5): *places* (indicated with circles) and *transitions* (indicated with segments).

A first variant of PNs terminology is the substitution of *places* with *resources* and *transitions* with *activities*. The aim is to simplify the rigorous language used in PNs theory, bringing it much closer to common language.

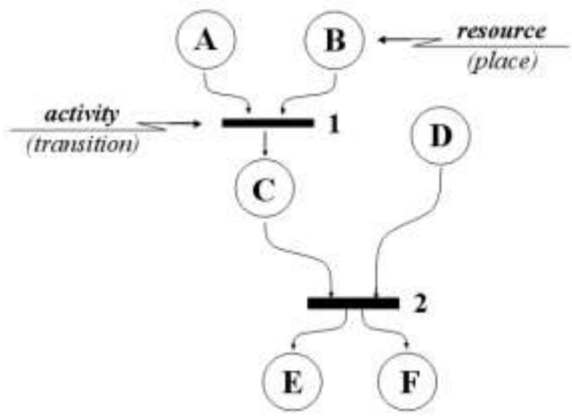

Figure 6.5 – An example of Petri Net

A graphic arc that is directed from a resource to an activity indicates that the resource is necessary to carry out that activity. Similarly an arc that is directed from an activity to a resource indicates that the resource is the product of the same activity.

What has just been listed are, so to speak, the basic "ingredients" to give shape to PN according to the use suggested within the experimentation referred to here. In actual fact, the theory presupposed by the PNs is much more articulated and rigorous (Peterson, 1981). In our case only the key concepts have been used to enable the two communities involved to assess the general philosophy governing the specific approach.

Just as for concept maps, ad hoc software environments have been developed also in the case of the PNs. By way of example, Figure 6.6 shows the dialogue screen of one of these environments, specifically that of WoPeD (<u>Wo</u>rkflow <u>Pe</u>tri Net <u>D</u>esigner).

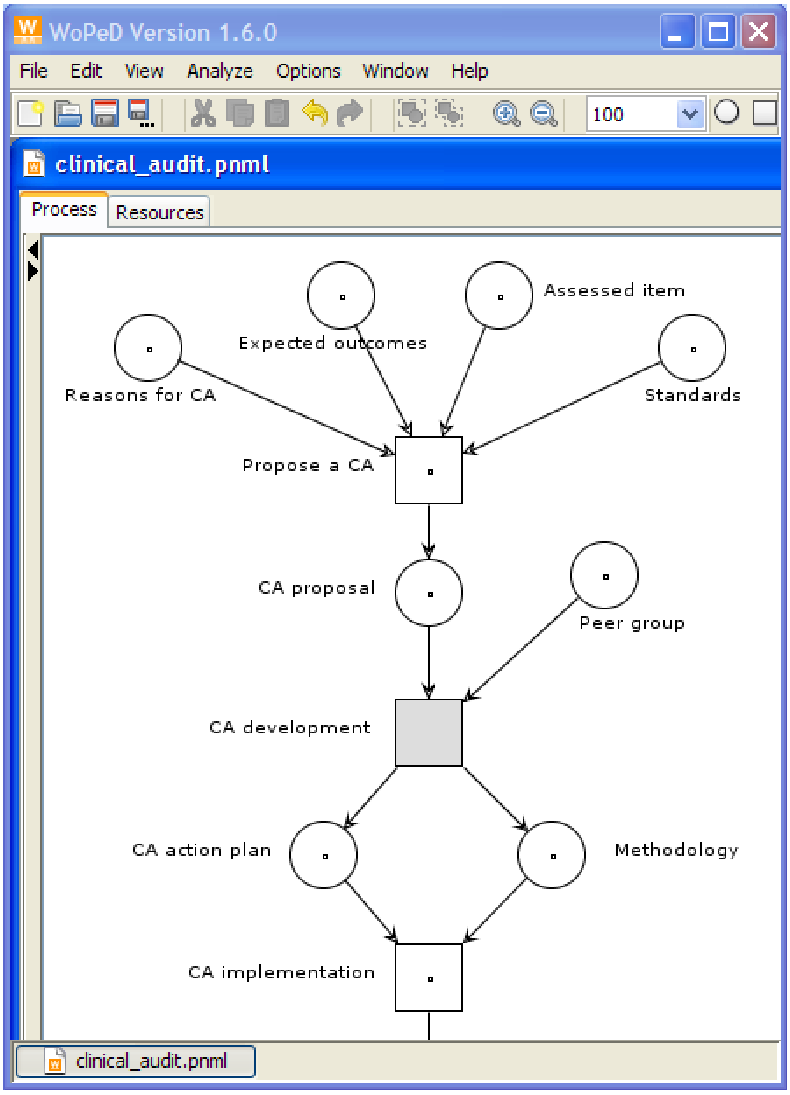

Figure 6.6 – Example of environment to edit and implement Petri Nets

The features of such applications not only provide an editing environment of PNs, but also check syntax functions and simulation of procedures/systems that they describe.

Successive refinements (top-down expansion)

Starting from an initial PN - in attempting to describe the process/procedure or knowledge domain with even greater precision - activities, resources and links are often increasingly added. This therefore produces very complex graphs that are hard to process and read. A good method to overcome this drawback is to describe the network through successive refinements (or stages), expanding it using a top-down approach (Trentin, 1991).

In the first stage an overall (undetailed) representation is given of what one wants to describe. The resources and main activities are reported together with their respective interconnections (Figure 6.6).

In the same network, the complex activities, that will be described in more refined detail in a specific sub-network, are then highlighted. See in Figure 6.6 the activity “CA development” represented with a grey square (this too is a graph) produced by one of the professional communities participating in the experiment).

The following stage involves developing the refinement sub-networks giving a detailed description of the more complex activities. For example, Figure 6.7 reports the refinement of activity “CA development” described in the PN of Figure 6.6.

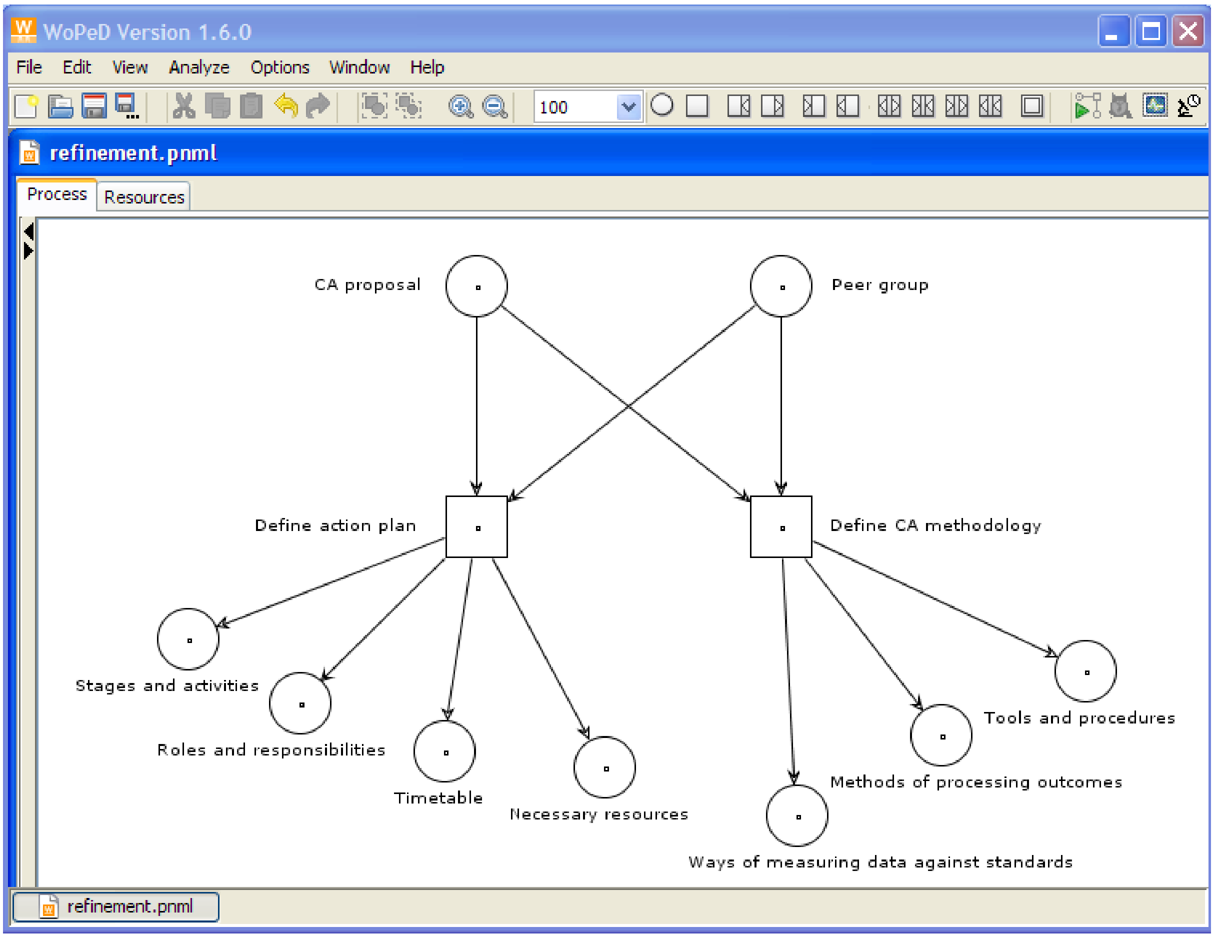

Figure 6.7 – Example of refinement derived from Figure 6.6

The refinement process is iterated until the desired level of detail given to the representation is attained.

The refinement activity is a consequence of the need to foster the so-called “functional abstraction” (Stein 2002), the process through which the attention of the individual or whole group/community focuses on one aspect of what is being described at a time.

This is a process developed stepwise. It begins with an overview of the subject matter, such as a professional issue, where the key elements characterising it are identified (macro-representation of the domain). In the following steps, each key element is isolated and described in more detail by breaking it down into less complex sub-elements (for example, a complex activity is broken down into sub-activities). This is done by trying to abstract as much as possible from what is within the confines of the element that is considered one by one (the other elements), to guarantee maximum success of its specific analysis.

Should this refinement step be inadequate for a deep analysis of the element being dealt with, the refinement process is iterated until the level of detail is considered the most functional to reach the final objective (analyzing a situation, solving a problem, describing a complex system).

RESEARCH METHODOLOGY

As mentioned earlier, one of the main aims of the experiment was to analyse and discuss the actual usability and effectiveness of the graphic representations proposed in fostering collaborative interaction and sharing of information, experiences and practices during a process targeted at developing knowledge on a specific professional issue/problem.

For this purpose, at the end of the collaborative activity the participants were given a questionnaire divided into 4 sections (Trentin, 2007):

A. Learnability, intended to pinpoint the times and possible learning difficulties of the approaches to the formal representation of knowledge used in the experimentation.

B. Study and/or problem-solving, intended to research the perception of the general usefulness of the tools proposed for the study activities, analysis and search for solutions.

C. Usefulness on an individual level in one's own professional practice, intended to research the perceived usefulness of tools proposed in relation to an individual use in one's own professional practice.

D. Usefulness in facilitating collaborative group work, intended to discover the perceived usefulness of tools proposed in fostering or not fostering group work when dealing with aspects related to their own professional practice.

In the questionnaire, two questions are associated with each survey indicator: one with a closed-ended answer based on attributing a score (on the Likert 1-5 scale); the other with an open-ended answer asking to explain the attribution of the above-mentioned score or to give further information about the same indicator.

25 participants belonging to the Audit community and 16 to the Alert community answered the questionnaire anonymously.

DATA ANALYSIS AND DISCUSSION

The survey data revealed positive evaluations regarding the professional use of proposed graphic formalisation methods. However, there were various and sometime considerable differences between what was expressed by the two communities. This likely to be related to the different roles covered by the respective individuals: on the one hand, positive but lower scores were given by the Audit community made up mainly of people with a managerial role; on the other hand, higher scores were assigned by the Alert community made up of staff with a more technical role.

A more analytical examination of the participants' answers is provided in the next section.

Learnability

As shown by Table 6.1, both groups stated that they found it more difficult to enter the logic of the PNs than the concept maps.

Learnability	***Audit***	***Alert***
How easy has it been for you to master the logic and syntax of the concept maps?	3,1	3,7

How easy has it been for you to master the logic and syntax of the Petri Nets?	2,6	2,8

Table 6.1 – Average data relating to answers on learnability (Trentin, 2007)

It is a fairly common reaction, met in other similar experimentations (Trentin, 1991; Stein, 2002), and should be related to the greater effort of abstraction (and of dissection) that the top-down development of a PNs requires. The free answers given by the participants show how the use of concept maps seems to best mirror their way of coping with professional problems i.e. considering the elements characterising them all together and simultaneously.

The use of the PNs, with a top-down approach, generally baffles the professional not used to functional abstraction mechanisms which are more familiar in information technology and engineering.

This was confirmed by directly observing the participants' first approach towards elaborating a PN where individuals tended to draw a very detailed, and therefore complex graph already at the overview stage of the knowledge domain.

Some open answers given by participants pointed out, among the probable causes of difficulties, how they are used to a sequential approach to analysing problems which is closer to the logic of flow-charts (used occasionally by some of them) than to the logic of top-down.

General usefulness for study activities, analysis and problem-solving

To best understand the convergences and divergences expressed by the participants on this point, we will firstly make a quantitative comparison of the average scores assigned by the two communities and then summaries the usefulness of the two approaches in relation to every single activity indicated in the questionnaire.

Quantitative comparison of the scores assigned by the two communities

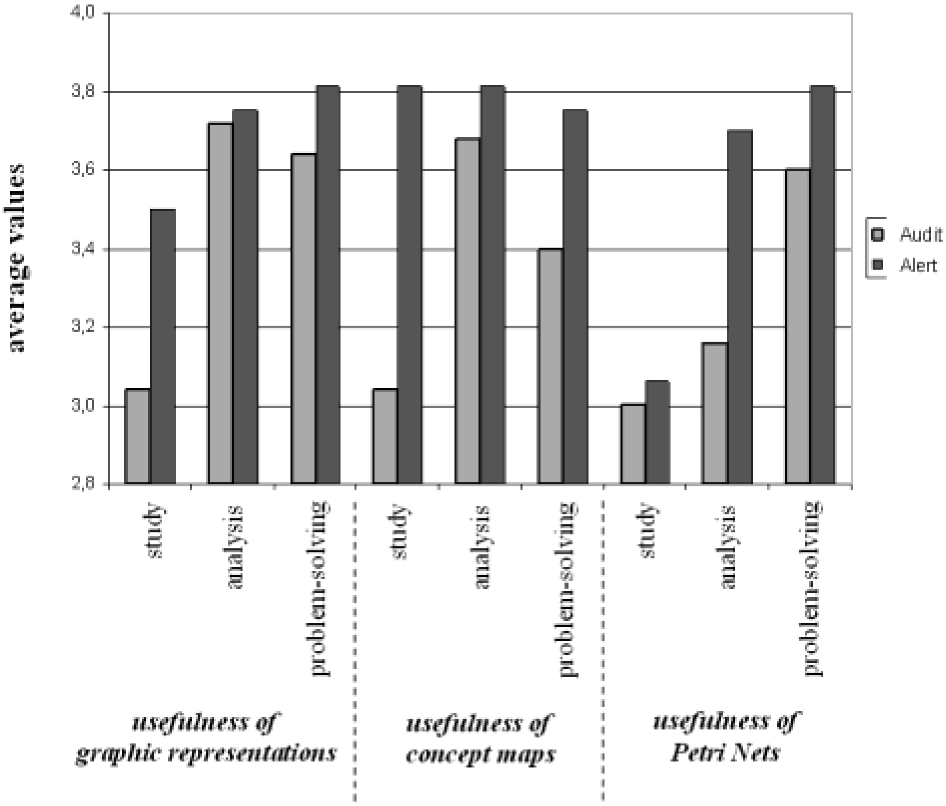

Figure 6.8 – Quantitative comparison between the average scores assigned by the two communities in relation to the usefulness of graphic representations in their profession

As can be observed in Figure 6.8, the trends of average scores attributed by the two communities are fairly similar even though they are quantitatively different. The only divergence that is rather noticeable corresponds to the use of concept maps for study activities. In this regard, 8 members of the Audit community justified the low score claiming that drawing up a concept map on a given topic can be done only if one already has sufficient knowledge about it. They therefore think that the use of the concept maps can be more useful as a self-check tool of one’s learning than as an aid to studying (in the sense of formal learning).

On the other hand, the rather high score attributed by the Alert community should be related to their idea of using the concept maps as a tool to support the collaborative study processes.

Summary on the different usefulness of the two approaches

Apart from the deviation between the quantitative evaluations formulated by the two groups and the above-described divergence, from the graph in Figure 6.8 it can be deduced that:

- the graphic representations are considered useful particularly for analysis and problem-solving activities and less useful for study activities. The evaluation of the Alert Community is an exception to this in correspondence with the use of concept maps;
- both communities showed concordance (despite attributing rather different average scores) in evaluating that the use of the concept maps are more recommended in analysis activities whilst that of the PNs in problem-solving activities.

To sum up, the participants indicate that the concept maps are more useful in describing "what it is" whilst the PNs in describing "what to do to".

Usefulness of graphic representations on a personal and group level

After the general considerations, described in the previous sections, participants were asked to evaluate the perceived usefulness of the two graphic methodologies as a tool for both personal and group use in their professional practice. Here are their evaluations:

Personal usefulness of graphic representations	***Audit***	***Alert***
How much do you think Concept Maps can/could be useful in your professional practice?	3,3	3,8
How much do you think Petri Nets can/could be useful in your professional practice, for the representation of procedural knowledge?	3,3	3,3
How much do you think Petri Nets can/could be useful in your professional practice, to describe complex situations/systems?	3,2	3,6

Table 6.2 – Average data relating to the personal usefulness of graphic representations (Trentin, 2007)

As can be seen, both communities gave between average and high average scores regarding the personal usefulness of graphic representations.

The attitude changes when instead the same tools are considered for collaborative group activities.

Usefulness of graphic representations in group work	Audit	Alert
How much do you think Concept Maps can/could be useful in group work?	3,7	4,1
How much do you think Petri Nets can/could be useful in group work, for the representation of procedural knowledge?	3,8	3,8
How much do you think Petri Nets can/could be useful in group work, to describe complex situations/systems?	3,7	3,9

Table 6.3 – Average data relating to the usefulness of graphic representations in group work (Trentin, 2007)

A comparison between Table 6.2 and Table 6.3 shows how the participants underline how graphic representations are more useful in group work than in individual work. Here, both communities have shown a certain convergence of opinion, although there are the usual deviations in average values.

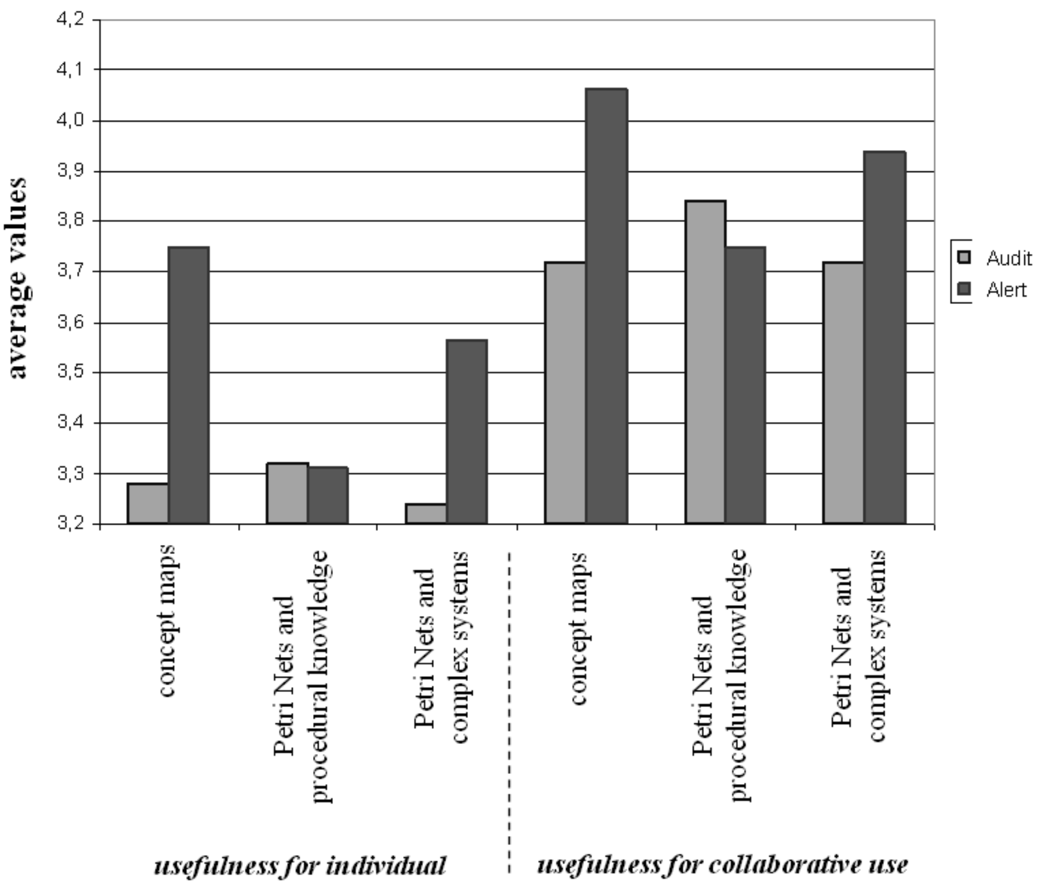

Figure 6.9 – Comparison between the average scores assigned by the two groups regarding the usefulness of graphic representations respectively for individual and collaborative use

From the diagram in Figure 6.9 it is interesting to observe how there is an appreciable divergence between the two communities regarding the usefulness of the PNs. The

Audit community believe they are more effective for representation activities of procedural knowledge. On the other hand the Alert community consider them more useful for those activities connected to the description/analysis of complex systems. This is for both individual and group activities. Again, the divergence of opinion is likely to be related to the members' role within the two different communities in the respective local health units.

CONCLUSIONS

Two interesting conclusions emerged from the experiment: the first concerning the use of graphic representations in formal and informal learning processes; the second concerning the combined use of two graphic tools for professional problem-solving.

Regarding learning processes, participants pointed out that graphic representation of a topic can only be achieved if one possesses sufficient knowledge of the topic. They thus retain that graphic representations can be more useful as a tool for self-assessing one's learning than as a study aid proper (i.e. in formal learning). Participants also consider it useful to employ graphic knowledge representation as support tools for informal collaborative learning.

Perhaps the most interesting result emerging from the research is the idea of combining the use of the two graphic tools for professional problem-solving activities (Trentin, 2007). In particular, as the participants indicate explicitly in some answers, the concept maps are believed to be more effective in analysing the knowledge domain related to the problem to be faced (description of *what it is*). On the other hand, the PNs are thought to be more effective in studying and describing the procedures to solve the very problem (description of *what to do to*).

Indeed this is confirmed by the typical stages characterising problem-solving strategies (Heller & Reif, 1984; Gick, 1986):

1. analysis of reference scenario related to the problem;
2. description of what is already known regarding the specific problem;
3. formalisation of the problem and of its possible breakdown into sub-problems;
4. identification of actions to undertake to provide a solution to the problem and/or individual sub-problems where it can be broken down;

5. identification of necessary resources to carry out actions determined in the previous point.

As can be observed, in the high stages (see points 1-2), where the question is to define the problem in terms of “what is it”, the concept map would in fact appear to be the most suitable tool. In the successive stages (3-4-5), the PNs would instead have the advantage of favoring the procedural description of “what to do to”, at a macro level (solution overview) as well as micro level (solution details to sub-problems comprising the general problem).

With regard to the procedural representation of knowledge, it is worth pointing out how some participants found PNs more effective than flow-charts in describing processes/solutions. This is due to at least two reasons:

- because besides indicating the link between activities characterising a process, PNs require the necessary resources for their development to be defined (flow-charts focus only on the statements);
- the top-down refinement helps focus step by step on the specific parts of the process and therefore avoids managing the complexity of what is being studied/analysed with just one graphic representation.

These are a fairly interesting conclusions that could lead to new developments in researching technological solutions to support the integration of the two methods of formal knowledge representation discussed here. The solutions need to be able to offer, through the same software environment, support functions to the conceptualisation and to the proceduralisation in problem-solving activities.

These activities, as is known, provide the ideal opportunity to trigger informal peer-to-peer learning processes which are typical in online professional communities.

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