INFORMAL LEARNING AND KNOWLEDGE FLOW IN CME: THE FACILITATING ROLE OF GRAPHIC KNOWLEDGE REPRESENTATION IN SOCIAL INTERACTION

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Abstract

Early approaches to knowledge management focused on knowledge as a thing, because in those days technology focused on codification, but neglected the flow aspects. Knowledge flows along existing pathways in organizations. If we want to understand how to improve the knowledge flow (KF), we need to understand those pathways (Prusak, 2003)[1]. This is a key aspect, and it has stimulated the reflections in this chapter as to how Graphic Knowledge Representations (GKR) can support, foster and enhance knowledge sharing and development processes in CME, through the activation of non-formal and informal knowledge flow dynamics.

The 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 concept 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 actual usability and effectiveness in fostering social interaction, knowledge-sharing and information exchange during a process designed to study a specific professional problem.

We will do this step by step, and will begin by proposing a graphic representation of the different facets of the learning process, differentiating them into formal, non-formal and informal and also into intentional and incidental. Thus, the informal component and its relationship with the horizontal knowledge flows which are typical of social interactions, will be identified. Finally, the above-mentioned experimental cases will be described and the results deriving from them will be discussed.

1. Larry Prusak in Anklam, P. (2003). KM and the social Network, *Inside Knowledge Magazine*. http://www.ikmagazine.com.

Introduction

In organisational contexts, the terms *formal, non-formal and informal learning* do not refer so much to the "formality" of a learning process as to the agent who establishes the aims and objectives of the process and directs the achieving of them (Cofer, 2000).

Thus in a "formal" learning process it is the manager of the learning course (e.g. the human resource development department – HRD Dept.) who establishes these objectives, while in an "informal" process it is the individual professional (or group of professionals) who define it on the basis of their knowledge and professional needs of the moment.

If in the organisation it is someone else (other than the HRD Dept.), for example a line manager in charge of the on-the-job training, who defines the learning aims and objectives, then we tend to speak of "non-formal" learning (Hanley, 2008).

Two other terms which are often used in speaking of formal, non-formal and informal leering processes are *incidental learning* and *intentional learning*, which substantially refer to how voluntarily the learning objective is pursued.

Learning aims and objectives, as well as the methods for pursuing them, are inherent to an "intentional" learning environment; while "incidental" learning occurs when the learner acquires something not planned by the learning environment, i.e. when the learner shifts the focus of the planned objectives onto other, unplanned objectives (Good and Brophy, 1990).

Figure 1 shows a possible representation of the learning process as an intersection between formal, non-formal and informal learning on the one hand, and incidental and intentional learning on the other.

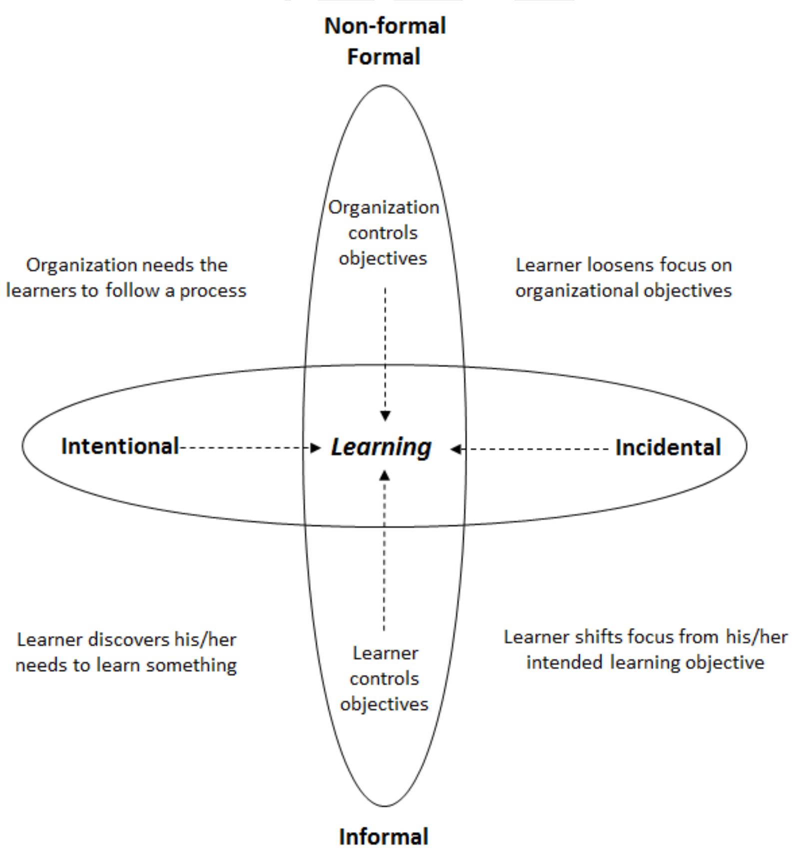

Figure 1. The learning process as a result of the intersection of formal, non-formal and informal learning on the one hand, and incidental and intentional learning on the other.

Thus, formal learning is normally always intentional. Informal learning is intentional if the learner sets an objective or goal for him/herself and incidental if the learning occurs haphazardly or by serendipity (Good and Brophy, 1990; Trentin, 2005).

The experiment described in this chapter lies halfway between the two left quadrants (formal/informal-intentional). In other words, given the declared learning need of the organization (*the organization needs the learners to follow a process*), the way in which we tried to meet it was based on activation within the learner community of a cognitive type of objective (resolution of a professional problem, acquisition of new specialized knowledge etc.) (*the learners discover their needs to learn something*).

The choice of this particular approach was also dictated by a further learning aim, more closely linked to method than to content, i.e. accustoming participants to perceiving and acting as an integrated professional community of practice.

Informal Learning And Knowledge Flow

The dynamics between tacit and explicit knowledge is a key factor in organizations. Knowledge is the result of a constructive process where subjective factors, such as pre-existing knowledge and experiences, individual and organisational cultures, and individual talents play a role of paramount importance. As a result, knowledge (1) is distributed across individuals, groups and organisations in an inhomogeneous way and (2) has a natural tendency to remain at least partially at a tacit level. This is especially true of experts who in most cases are not fully aware of their mental models and of the methods they apply when accomplishing a given task. Usually it is difficult for experts to transfer knowledge from the tacit to the explicit realm. Expertise in fact consists of a very complex, though pragmatically efficient, structure involving different types of knowledge which are activated by the expert within the context of specific tasks (Basque et al., 2008; Chi et al., 1981; Stemberg, 1999).

Knowledge management within organisations is aimed at fostering the process of the continuous construction and maintenance (1) of a shared body of knowledge and (2) of an efficient network where different individuals, groups and sectors of an organisation can interact, share and rely on one another. Knowledge management attributes a special importance to knowledge flows, i.e. those processes which involve the transformation, construction, communication and sharing of knowledge, because it has been shown that they are crucial to the efficacy and good performance of the organisation (Nissen and Bordetsky, 2011).

The difficulty of making explicit, communicating and sharing tacit knowledge has a direct influence on the very conception of knowledge management. The inadequacy of approaches based on document creation and sharing through appropriate storage facilities has been widely recognised, and the importance of providing direct support for the processes of transformation, collaborative construction and communication of knowledge has been clearly identified (Apostolou et al., 2000).

The terms *knowledge flow* or *communication of knowledge* are commonly used. However, if interpreted literally, they are intrinsically contradictory. Knowledge is subjective in nature; only data and information and, at most, knowledge representations can flow, and those representations only make sense in relation to human cognition, i. e. communication is only achieved when the data received become meaningful for the receiver as the result of the action of his/her cognition faculty (Carvalhoand Araújo Tavares, 2001).

Representations are something different from actual knowledge, but they can be an important aid for supporting the processes of thinking and communication.

The SECI model

To discuss the role of knowledge representations in enhancing and facilitating knowledge flows, the Nonaka (1994) model will be adopted as a frame of reference (Figure 2). This model moves beyond previous approaches mostly focused on information flows, and assumes an epistemological value by making explicit how new knowledge is generated and how it can propagate across an organisation. Both individual and social aspects are taken into account in the model.

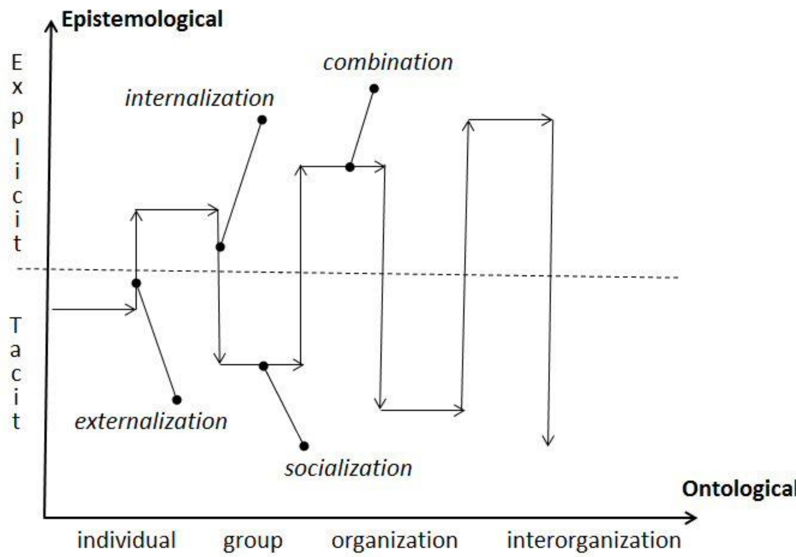

Figure 2. The Nonaka spiral model of knowledge flow dynamics as adapted by Nissen and Levitt (2002)[2].

The model, which is schematized in Figure 2, represents growth and propagation of knowledge as a process characterized by a continuous, *spiral* dynamics between two poles: the level of *tacit* knowledge and the level of *explicit* knowledge (Polanyi, 1966).

According to the model, knowledge evolves and propagates according to a cycle made up of four different knowledge-building mechanisms operating within and across the tacit and the explicit levels: *externalization*, *combination*, *internalization* and *socialization*.

Externalization is the process leading from tacit knowledge to explicit knowledge. The process is intrinsically non-linear, and requires going back and forth from the explicit to the tacit level until a satisfactory degree of explicitation/formalization is achieved. According to Nonaka, collective reflection is one of the triggers of externalization: the dialogue between individuals acts as a stimulus to the recognition, shaping and then formalising of tacit knowledge.

2. http://cife.stanford.edu/sites/default/files/WP076.pdf (p. 7).

Combination is a phase which takes place almost entirely at the explicit level and corresponds to a definite advance in the construction of organizational knowledge. It requires documenting externalized knowledge, combining it with the knowledge externalized by other people or by other sectors of the organization, and connecting/integrating it with the existing knowledge of the organisation.

Internalization is a knowledge conversion process where the explicit knowledge of groups or organisations becomes the tacit knowledge of individuals through an experiential process of understanding, applying and doing. It is a path leading from the objective dimension (which is the aim of externalization) to the subjective dimension (which is the domain where knowledge is put into action).

Socialization is a process which fosters the exchange of tacit knowledge among individuals. It is based on capturing knowledge through direct interaction with other people, regardless of whether they belong to the same team or are external to the organization. It depends on a process of sharing experiences and perspectives. The real trigger of this process is a common field of interaction.

The spiral behaviour displayed in Figure 2 demonstrates that the same cycle may recur many times, progressively involving larger sectors of an organization, and may extend to different organizations as well.

The four phases of the SECI model do not correspond simply to a transfer of information. Each of them implies (1) a process of construction either of new knowledge or of a new type of knowledge and (2) some kind of knowledge sharing and propagation which may take place either contextually with the knowledge building process or as a result of the construction of an explicit, (therefore shareable) documentation of knowledge.

Information Flow and Knowledge Flow

Figure 3 is a diagram of a communication system as conceived by Shannon and Weaver (1949): an information source, an information codification and transmission unit, a transmission channel with noise interference[3], an information receiver and a decodification unit, the destination of the information.

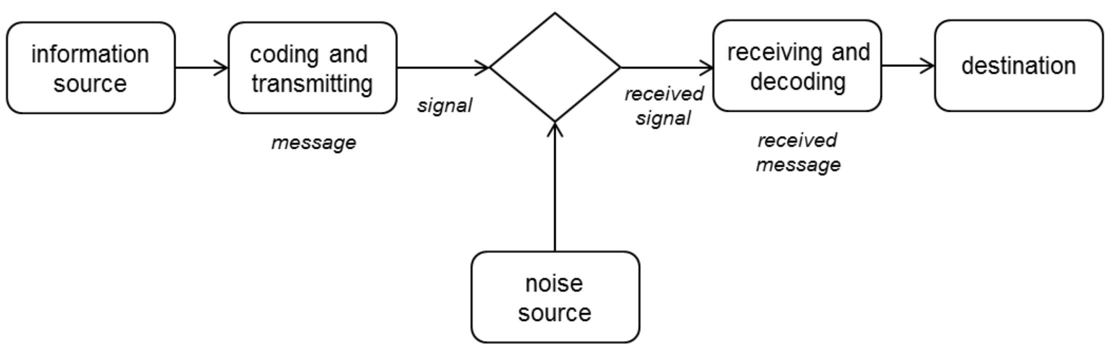

Figure 3. Communication flow according to the model of Shannon and Weaver (1949).

3. In communication theories the concept of "noise" is considered in its broader sense. Besides the actual physical noise introduced by technology (e.g. electromagnetic perturbations), it includes noise caused by the following: semantic factors (i.e. different interpretations of the meaning of what is being communicated); entropy and overabundance of information transmitted; difference in interlocutors' cultural levels; technical jargon of the specific communication context, etc.

This type of communication is at the basis of both dialogic interaction (e-mails, forums, social networks, etc.) and artefact-mediated interaction (documents, wikis, conceptual maps); in other words, every time a piece of information needs to be first coded then decoded in order to pass through the technological channel.

Clearly, the principle by which it is coded must be the same as the one by which it is decoded, and this leads to the need for a syntax which all the interlocutors (mediated by technology) must respect.

The syntax may be that of the natural language in which a text artefact (e.g. a wiki) is written, or in which a verbal exchange occurs, or it may be a formal language, as in the case of graphic representations (e.g. concept maps).

Apart from its need for codification, the process illustrated in Figure 3, information transmission, does not differ greatly from the flow of a liquid from one container to another. And this is why it is often defined as an information flow (IF). While Figure 3 adequately represents an IF process, it is inadequate for representing KF processes. In fact as Steen Larson states:

"Information can be transmitted but knowledge must be induced" (Larsen, 1986)

In support of his theory he listed the three key stages which in his opinion bring about the flow of knowledge from a source to a receiver:

- *transformation of personal knowledge into public information* - The senders transform and organize their knowledge into public information to be transmitted to the receiver;
- *information transfer* - The senders transmit their knowledge, transformed into public information;
- *transformation of the public information into personal knowledge by the receiver* - The receiver transforms the information provided by the sender into personal knowledge.

In other words, the mechanisms for the acquisition of new knowledge must not so much be comparable to the decanting of a liquid from one container (the sender's head) to another (the receiver's head), as rather a process involving absorption, integration and systematization of the information received by the receiver into his/her own pre-existing cognitive structures, which are the result of personal experience, earlier knowledge, etc.

In formulating this hypothesis, Larsen clearly espouses some established learning theories, in particular the theory of Meaningful Learning proposed by Ausubel (1968), which describes how new knowledge must be constructed based on the learners' prerequisite knowledge, named "superordinate concept". Gagne (1985) also suggested that prior knowledge is the necessary internal condition of learning. Thus, how to provide meaningful learning activities according to learners' ability of conceptualisation is an important and challenging issue in improving learning efficacy.

On the basis of these considerations, for a better representation of a KF process the scheme of Figure 3 should thus be extended as shown in Figure 4 (Trentin, 2011a).

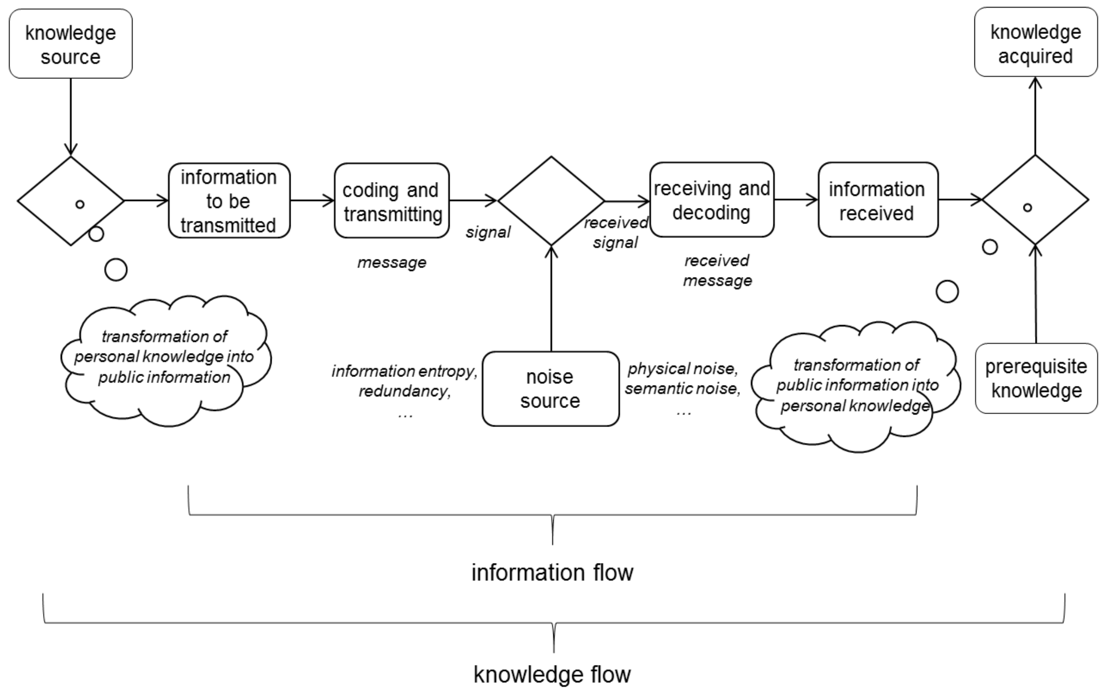

Figure 4. From Information Flow to Knowledge Flow[4].

Thus, the key point is to create the conditions for stimulating and favouring the process of *assimilation* and *accommodation* (Piaget, 1977), by proposing both individual and collaborative learning activities, problem-solving and artefact development, etc. (Trentin, 2010).

In this context, an interesting approach to the fostering of collaborative knowledge building (Scardamalia and Bereiter, 1994; Stahl, 2000) is the integration of face-to-face and online interactions into the virtual community environment, in other words putting into practice what is described in Kimmerle and colleagues' *co-evolution model* (Kimmerle et al., 2010; 2011), centred on the use of technologies which favour social interaction.

When we speak of social interaction, we are often referring to resources such as forums, wikis and social networks, but we should not forget other tools which equally effectively foster dialogue, collaborative interaction and *knowledge maturing* (Kaschig et al., 2010) within the professional communities.

Of these tools, those for graphic representation have often shown their versatility in illustrating concepts, processes and other forms of knowledge (Donald, 1987; Trentin, 1991; 2007; 2011b; Olimpo, 2011).

Take for example Figure 4, and try to compare an exclusively verbal description of it with the one supported by graphics. Very probably, an exclusively verbal description would have proved less effective, or at least less effective in representing the conceptual image of the author of this chapter.

In other words, graphic representation facilitates the alignment of the two individual conceptual images of the sender and the receiver of the concept. In fact Figure 4 shows both

4. Figure published in Trentin, G. (2011a)(p.160). Conclusive thought on communication flow, knowledge flow and informal learning. In G. Trentin (Ed.), *Technology and Knowledge Flow: the power of networks*, Ch. 7 (pp. 157-165). Cambridge, UK: Chandos Publishing Limited. ISBN 978-1-84334-646-3.

the physical noise introduced by the technological channel and the semantic noise, i.e. interference related to a different way of understanding a word, a sentence, a concept, above all when the communication is not only exclusively verbal but also mediated. These different interpretations are often due to the different contexts in which the KF is developed (schools, companies, amateur associations etc.), as well as to the features of the interlocutors (age, education, culture, professional skills, etc.).

Empowering Knowledge Flows By Knowledge Representations

Tools of representation for both conceptual and technological knowledge play a key role in the SECI cycle (Figure 2). They assume a different meaning and a different degree of importance according to the nature of the specific phase being considered. It is quite obvious that representations are more relevant to those phases which have to do with the explicit level, i.e. externalization, combination and to some extent internalization, and are less important for socialization, where interaction among people is on the level of non-formal exchange and collaboration.

In this framework, the most important meanings of representations are as follows.

Means for giving structure to tacit knowledge

In the context of an organization, tacit knowledge should become explicit and *objectivized*. It is worth mentioning that representation tools should not only be meant as instruments to give shape to the *final* knowledge representation, i.e. the output of the externalization process. They also have a constructive role within the process of externalization, where they may assume an actual maieutic value: when the nature of a representation language (determined by its internal constraints) is in tune with the knowledge to be represented, then identifying and connecting concepts, making abstractions, reasoning, are all facilitated and enhanced.

Set of ontological commitments

Representations give "an answer to the question: in what terms should I think about the world?… all representations are imperfect approximations to reality, each approximation attending to some things and ignoring others, then in selecting any representation we are in the very same act unavoidably making a set of decisions about how and what to see in the world … the commitments are in effect a strong pair of glasses … bringing some part of the world into sharp focus, at the expense of blurring other parts." (Davis et al., 1993). Donning this pair of glasses is a necessary condition for building explicit knowledge which necessarily refers to a specific and limited part of the world.

Vector of knowledge

Communication should be easy, efficient and unambiguous. Natural language alone is not an efficient means for communicating structured knowledge because of its intrinsic nature which is *serial* (words and concepts must flow as a logical and temporal sequence) and *evocative* (the same sentence may evoke different meanings for different human receivers). Serial communication does not provide directly holistic perspectives (which are a key factor for knowledge flows), but rather leaves the task of building those perspectives to the receiver. Evocative communication necessarily implies a considerable degree of ambiguity because different receivers may have different cognitive reactions to the same message. Without excluding natural language, a wise use of knowledge representations may significantly contribute to overcoming its above-mentioned limitations. Representations are built in terms of artificial languages which may be able to directly provide a global picture of the thing being represented (this is especially true for graphic languages). Besides, in most cases the ontological components of representation languages have a formal or quasi-formal definition which favours a more focused cognitive reaction in the target receiver.

Support for collaboration

The use of representations has a direct impact on the collaborative knowledge construction processes which typically take place in the phases of externalization and combination. According to Suthers (2006), representations "mediate collaborative learning interactions by providing learners with the means to express their emerging knowledge in a persistent medium, inspectable by all participants, where the knowledge then becomes part of the shared context". In particular, representations can: (a) foster negotiation because when several actors may add to or change a representation they are naturally led to obtain agreement on their contribution from the community; (b) act as referential resources because building a representation together means participating in the construction of a meaning which can be re-invoked at a later stage for further processing; and (c) stimulate mutual awareness because others' contributions to the representation will influence individual choices.

Support for dealing with complexity

Often the knowledge to be shaped or communicated and shared is intrinsically complex since it involves many aspects of reality and the many relations among them. An expert may easily integrate the tacit and the explicit levels and deal with a large body of knowledge with a high level of complexity. However the human mind, working at the explicit level, can only deal with a few elements at a time and needs to be empowered by the use of specific conceptual tools in order to be able to manage complex knowledge. One of the key roles of representations is that of supporting the human mind in this effort. However it must be noted that complexity cannot be efficiently tackled only using conceptual tools. When the reality is complex, representations reflect that complexity and appropriate technical tools are required to support specific conceptual models. It is worth mentioning that complexity is not the only reason for using technical tools. Editing, collaborative building, storing, visualizing, accessing and navigating, associating and combining, sharing representations are some of the practical reasons which make the choice of the proper tool for representation-based knowledge flow a critical one.

Medium for pragmatically efficient computation

In computational systems, representations can be used to support the users involved in a process of knowledge construction, organisation and sharing (Davis et al., 1993).

A representation expressed in a form which is computable and perhaps executable makes it possible to perform different forms of correctness verification, to generate equivalent representations or different forms of visualisation which may favour understanding and internalization, and to support intelligent editing, giving constructive suggestions during the representation building process.

Table 1 provides a synthesis of the importance of the different meanings of representations in the different phases of the SECI cycle (Olimpo, 2011).

Table 1. Roles of representations in the different phases of SECI cycle

	PHASES OF SECICYCLE			
ROLES OF REPRESENTATIONS	***externalisation***	***combination***	***internalisation***	***socialisation***
giving structure to tacit knowledge	yes	no	no	no
establishing ontological commitments	yes	yes	some	no
vectors of knowledge	some	yes	some	some
support for collaboration	yes	yes	no	some
support for dealing with complexity	yes	yes	some	some
medium for efficient computation	yes	yes	no	no

Some General Properties of Representation Languages

In this section some general properties of representation languages which appear particularly relevant for supporting knowledge flows are identified (Olimpo, 2011). They are (1) *expressive power*, i.e. the ability to accommodate all the important information; (2) *facilitating power*, i.e. the ability to facilitate expression and communication, which is especially important in the case of complex knowledge; and (3) *computability*, a property required for building information systems which are capable of providing intelligent support for the process of knowledge construction, organization and sharing. *Focusing power* will also be considered as a special case of *expressive power*.

Expressive power

The concept of expressive power has been formally defined by computer scientists in connection with programming languages; see for instance Dantsin et al. (2001). The term refers to the question: *what kind of knowledge can be expressed in a given language?* On the one hand, the expressive power of a graphic representation language is determined by its specific intrinsic constraints (type of entities and links allowed, rules which determine the types of graphs which can be built, possible rules defining how the representation can evolve), which make it possible or impossible, easy or difficult to associate specific semantic values with different structural components. On the other hand, knowledge types may differ in a variety of aspects: the nature of the thing being represented (static *vs* dynamic, concrete *vs* abstract), its degree of complexity, the required level of detail, the required level of generality (i.e. the possibility of incorporating different points of view). As a consequence, expressive power cannot be considered as an absolute property of a representation language, but rather as an attribute of the relation between representation languages and possible types of knowledge.

A particular aspect of expressive power is the *focusing power*, i.e. the possibility of providing a well-*focused* representation of a given type of knowledge. If, for a given type of knowledge, only *blurred* representation can be built, i. e. representations where only the general shape of knowledge is captured but important structural and/or semantic details cannot find room, that is a limitation of the focusing power.

Considering the six meanings of representation which have been identified for knowledge flows, expressive power is mostly (but not exclusively) relevant for *giving structure to tacit knowledge* and for establishing a *set of ontological commitments*, i.e. expressing which aspects of a given reality must be taken into consideration.

Facilitating power

This property of representation languages corresponds to the question: *How easily can we express knowledge in a given language?* This very general question corresponds to different more specific questions: "How well does a language function as a medium of communication? … How easy is it for us to 'talk' or think in that language? What kinds of things are easily said in the language and what kinds of things are so difficult as to be pragmatically impossible?" (Davis et al., 1993). The last question highlights that expressive power and facilitating power, though conceptually distinct, are not fully independent of each other; a language where something is very complex or difficult to express (low facilitating power) is practically equivalent to a language with a limitation in expressive power.

One very important aspect of facilitating power is the facilitation offered by a representation language for building and communicating complex knowledge. Excluding computational aspects, facilitating power is strongly influential for all the meanings of representations mentioned in the previous section.

Computability

Any knowledge representation based on graphs exhibits a minimum level of computability: graphs are formal objects which can be described in terms of relational algebra and it is always possible to apply specific algebraic operations to them. Therefore they can be manipulated and visualized in different ways by automatic means. Here the term 'computability' refers to the possibility of reaching beyond that minimum level and automatically performing semantically meaningful operations on a representation (for instance inferences). A particular aspect of computability is the possibility of *executing* a representation. This property is provided by those languages, such as Petri Nets (Peterson, 1977), which include a set of formal rules to guide the evolution of specific representations through a succession of possible states. The execution of a representation is meaningful from different points of view: simulating the behaviour of the *thing* being represented, testing the correctness of a representation, facilitating communication, etc.

Graphic Knowledge Representation, Social Learning and Knowledge Flow

Graphic representations facilitate alignment of the participants' varying conceptual images, helping reduce what is often defined as "semantic noise" (Shannon and 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 and 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 and 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.

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 (Trentin, 2011b). The first (Audit community) was made up of 33 head physicians and health care managers pertaining to Local Health Unit 11 of Leghorn (Tuscany Region) who had the task of dealing with the theme of the Clinical Audit, the key elements characterising it and the working methods to carry it out. The second (Alert community) was 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 concerning 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 (LHAs) 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 (a) could be easily added to and updated and (b) offered 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 artefact;
- wikis were used for collaborative online implementation of the artefact (i.e. the handbook on the assigned theme); wikis were proposed because we wished to create an artefact 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 and 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 Chapter 7 of this book[5], 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 knowledge representation. The development of each graphic representation was divided into three stages (Trentin, 2007):

- a face-to-face meeting for preliminary familiarization 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;

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[5]. Trentin, G. (Ch. 7). An Approach to Evaluating Contributions to Wiki-Based Collaborative Writing in an Informal Learning Context. *Network-based Continuing Medical Education*, Ch. 4. Nova Science Publishing.

- sharing of graphic representation and convergence towards one single sub-group version of it.

To co-construct the two representations the following applications were used:

- CMapTool[6] and WoPeD (Workflow Petri Net Designer)[7] respectively for the development of concept maps and Petri Nets;
- Moodle as the environment for running 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 formalized 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: 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 that theoretical and procedural knowledge-sharing processes 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 the 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 organization of informative, documentary and factual material contained in the community memory (Lave and Wenger, 1991). The latter 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[8].

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

6. http://cmap.ihmc.us/
7. (http://www.woped.org/)
8. For example http://www.webbrain.com.

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 and 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 5).

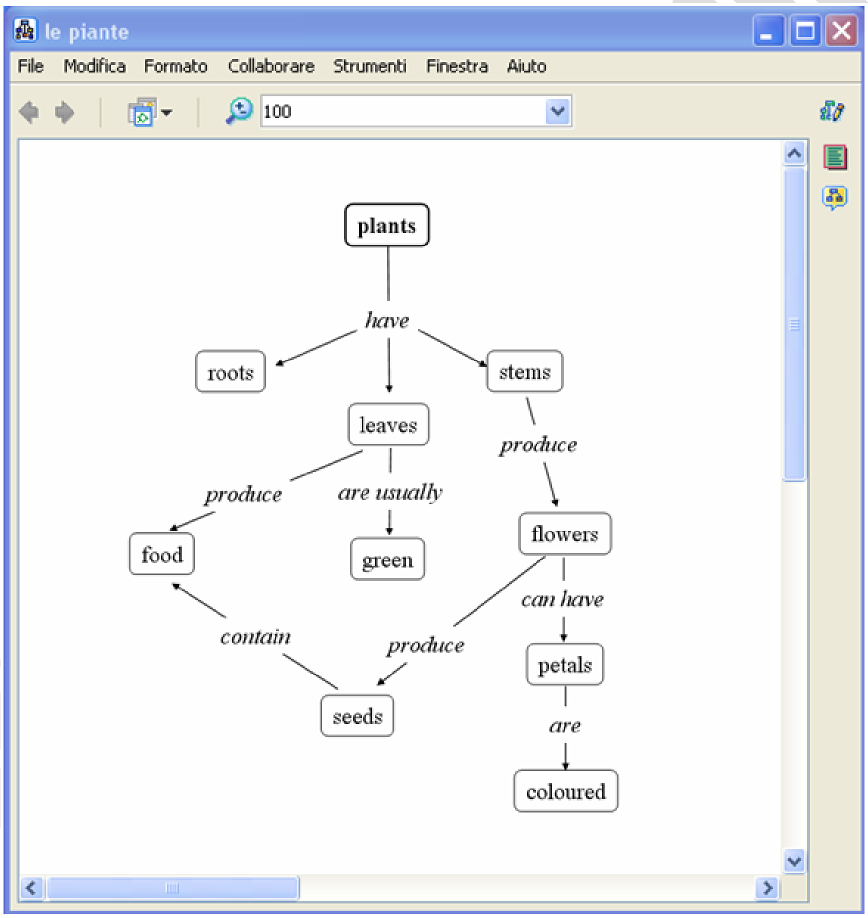

Figure 5. Example of a concept map drawn with CMapTool.

Besides the two basic features, a concept map is 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 5 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 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 6a);
- by clicking on and dragging the arrow one can create a link between a new concept and the starting concept (Figure 6b);
- then the two concepts and the relation type linking them are specified (Figure 6c).

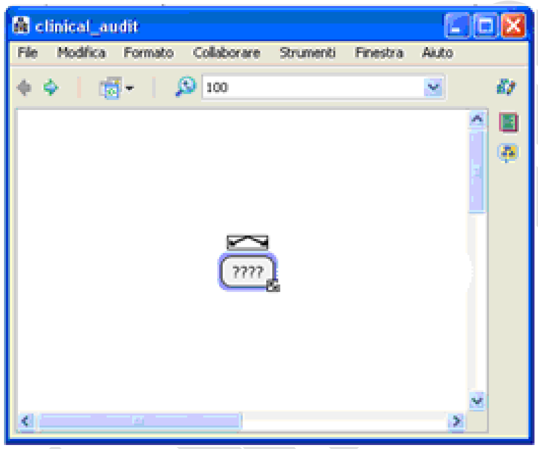

Figure 6a. The starting concept.

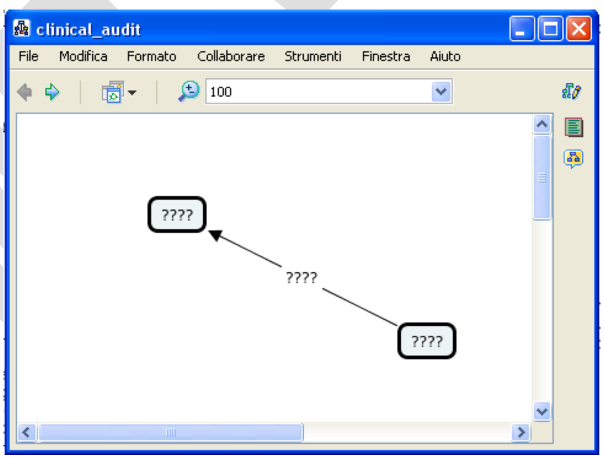

Figure 6b. The link between two concepts.

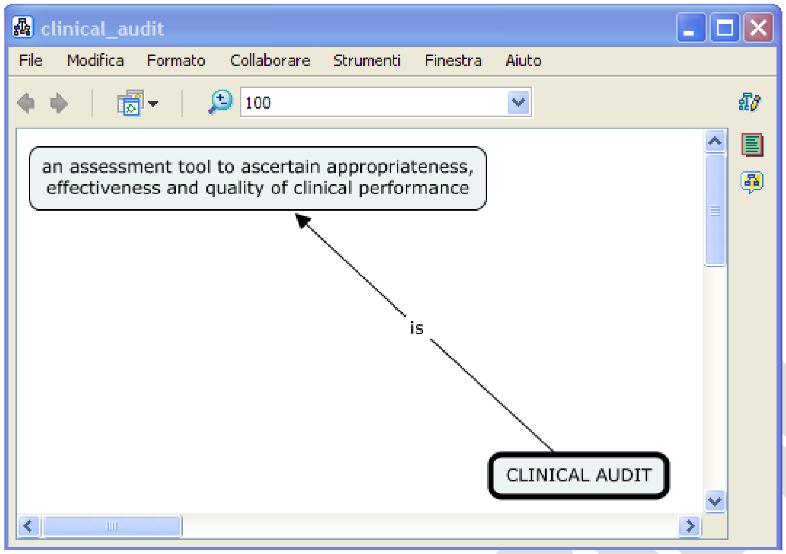

Figure 6c. Description of concepts and relation types.

By proceeding in such a way, one can obtain graphic representations like the one reported in Figure 7, showing one of the maps produced by the Audit community during the experimentation described here.

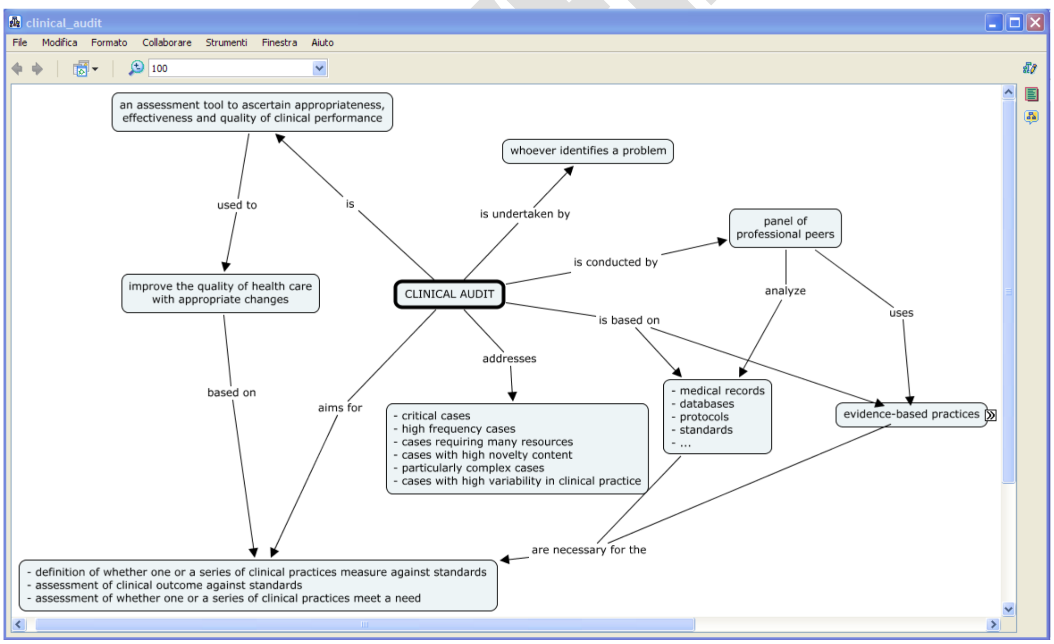

Figure 7. A concept map on the clinical audit developed with CMapTool.

When very complex knowledge domains have to be described, such as the clinical audit in Figure 7, 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 8). Then clicking on the symbol “<<” will take you back to Figure 7.

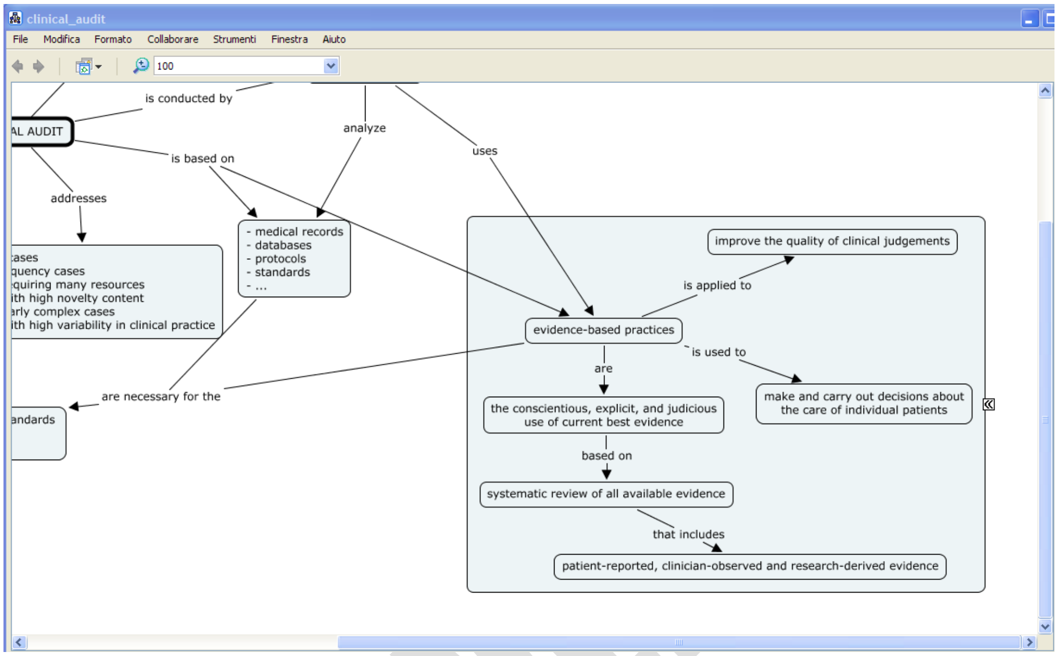

Figure 8. Example of a complex concept expansion.

Petri Nets and procedural knowledge representation

Petri Nets (PNs) provide an effective way to describe and analyse models, whether complex systems, processes or knowledge domains, etc. (Peterson, 1981). On account of this characteristic, they are often used in the graphic representation of procedural knowledge.

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 **-** PN is an oriented graphic in which two node types are represented (Figure 9): places (indicated with circles) and transitions (indicated with segments). A first variant of PN terminology is the substitution of *places* with *resources* and *transitions* with *activities*. The aim is to simplify the rigorous language used in PN theory, bringing it much closer to common language.

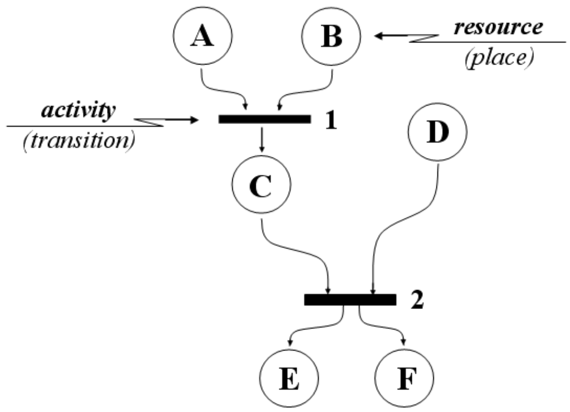

Figure 9. An example of Petri Net.

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 that activity.

What have just been listed are, so to speak, the basic "ingredients" to give shape to PNs according to the use suggested within the experimentation referred to here. In actual fact, the theory presupposed by 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 PNs. By way of example, Figure 10 shows the dialogue screen of one of these environments, specifically that of WoPeD (Workflow Petri Net Designer).

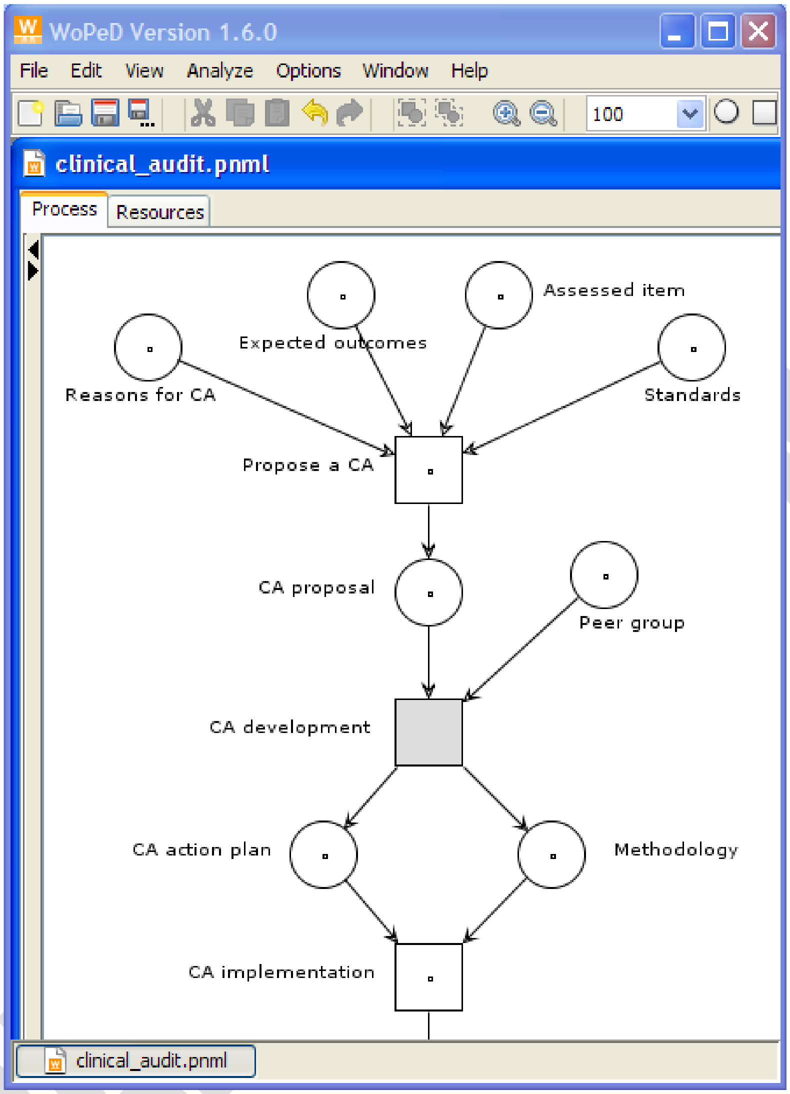

Figure 10. Example of environment for editing and implementing Petri Nets.
(CA stands for Clinical Audit)

The features of such applications not only provide an editing environment for 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 increasingly often 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 10).

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 10 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 11 reports the refinement of the activity "CA development", described in the PN of Figure 10.

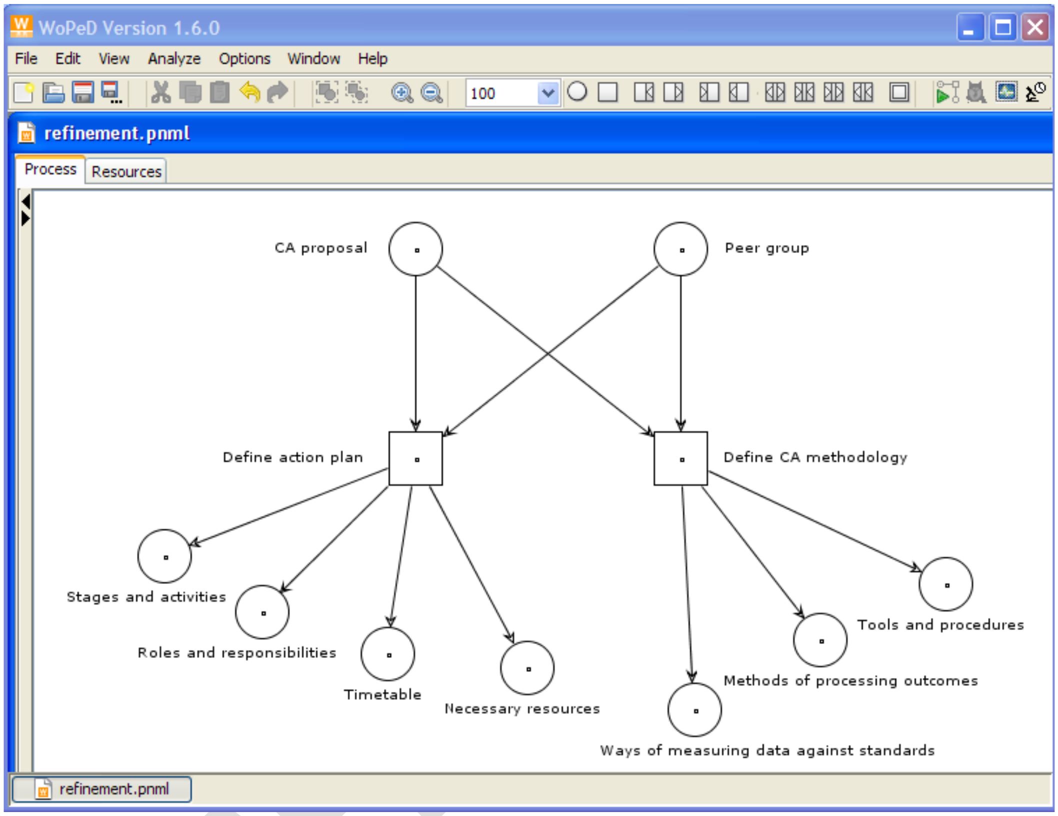

Figure 11. Example of refinement derived from Figure 10.

The refinement process is iterated until the desired level of detail requested in 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 all the other elements which border on the element under consideration, in order to guarantee maximum accuracy in the analysis of that given element.

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 for achieving 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*, aimed at researching 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 group work when dealing with aspects related to one's 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 the compiler 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 sometimes considerable differences between what was expressed by the two communities. This is 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 2, both groups stated that they found it more difficult to enter into the logic of PNs than that of concept maps.

Table 2. Average data relating to answers on learnability (Trentin, 2007)

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

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 PN 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 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 processing 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 suggested, as one of the probable causes of difficulties, that 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 summarise 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

As can be observed in Figure 12, 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 is 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 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 is attributable to their idea of using concept maps as a tool to support collaborative study processes.

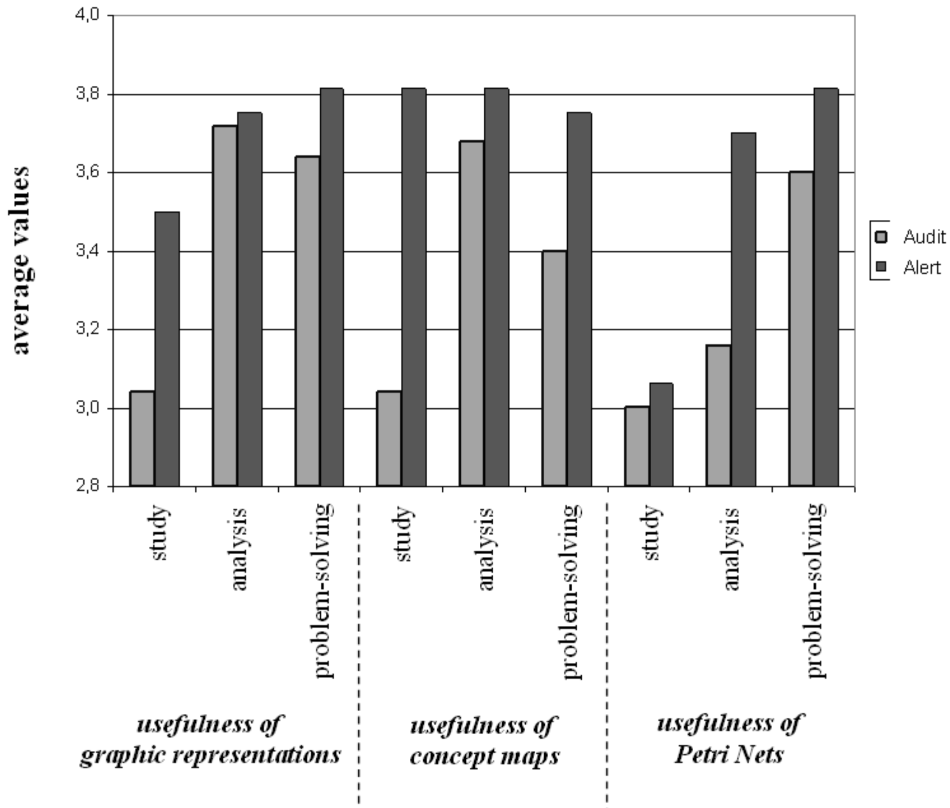

Figure 12. Quantitative comparison between the average scores assigned by the two communities in relation to the usefulness of graphic representations in their profession[9].

Summary of the different usefulness of the two approaches

Apart from the difference 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:

- 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 with regard to the use of concept maps;
- both communities showed agreement (despite attributing rather different average scores) in recommending the use of concept maps more for analysis activities and of PNs more for problem-solving activities.

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

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[9]. Figure published in Trentin, G. (2011b)(p.150). Graphic knowledge representation as a tool for fostering knowledge flow in informal learning processes. In G. Trentin (Ed.), *Technology and Knowledge Flow: the power of networks*, Ch. 6 (pp. 157-165). Cambridge, UK: Chandos Publishing Limited. ISBN 978-1-84334-646-3.

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 for both personal and group use in their professional practice. Here are their evaluations.

Table 3. Average data relating to the personal usefulness of graphic representations
(Trentin, 2007)

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

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

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

Table 4. Average data relating to the usefulness of graphic representations in group work
(Trentin, 2007)

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

A comparison between Table 3 and Table 4 shows how participants underline that graphic representations are more useful in group than in individual work. Here, both communities have shown a certain convergence of opinion, although there are the usual deviations in average values.

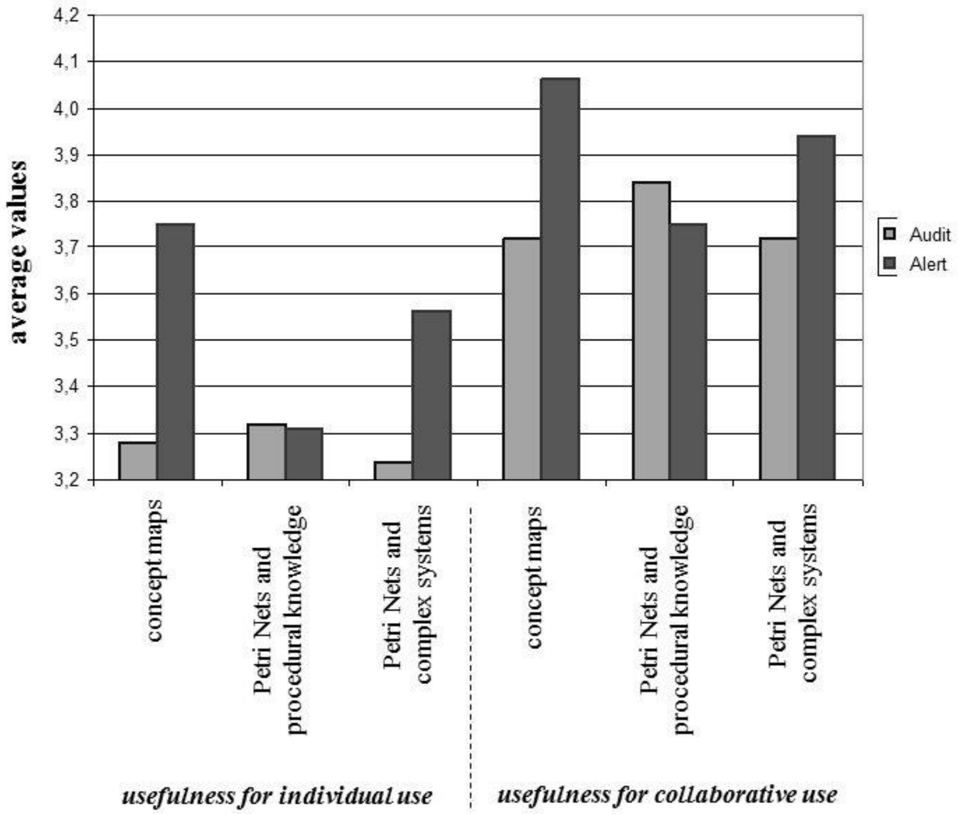

Figure 13 – Comparison between the average scores assigned by the two groups regarding the usefulness of graphic representations respectively for individual and collaborative use[10].

From the diagram in Figure 13 it is interesting to observe how there is an appreciable divergence between the two communities regarding the usefulness of PNs. The Audit community believe they are more effective for activities of representation 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.

Conclusion

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

[10]. Figure published in Trentin, G. (2011b)(p.152). Graphic knowledge representation as a tool for fostering knowledge flow in informal learning processes. In G. Trentin (Ed.), *Technology and Knowledge Flow: the power of networks*, Ch. 6 (pp. 157-165). Cambridge, UK: Chandos Publishing Limited. ISBN 978-1-84334-646-3.

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 a support tool 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; 2011b). In particular, as the participants indicate explicitly in some answers, 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, PNs are thought to be more effective in studying and describing the procedures for solving problem itself (description of *what to do to*). This is in fact confirmed by the typical stages characterising problem-solving strategies (Heller and 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 in order to provide a solution to the problem and/or individual sub-problems where it can be broken down;
5. identification of necessary resources for carrying 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 it is", the concept map would in fact appear to be the most suitable tool. In the successive stages (3-4-5), PNs would instead have the advantage of favoring the procedural description of "what to do to", at both ~~a~~ macro level (solution overview) and micro level (details of solutions 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 having to manage the complexity of what is being studied/analysed with just one graphic representation.

These are 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 functions which support conceptualisation and proceduralisation in problem-solving activities, through the same software environment.

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

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