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KNOWLEDGE AND PROBLEM SOLVING: A PROPOSAL FOR A MODEL OF INDIVIDUAL AND COLLECTIVE LEARNING

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I. Introduction

The purpose of this model is basically to develop a language that makes it possible to talk about knowledge and learning in a precise way. In fact, one of its main goals is to enable us to talk about collective learning (and, eventually, about what in the literature has been called "organizational learning") in a more precise way than has been possible in the past.

One important issue in this area is how knowledge becomes collective and how additions to collective knowledge come about through collective or organizational learning. Inevitably, this has to do with individual learning and how it gives rise to collective and organizational learning (OL). Many "accepted" definitions of organizational learning (see Sieber, 1998) state that there is more to OL than the sum of the individual learning of all the members of an organization. But it is not clear how or why.

Thus, the model needs to start with basic definitions of knowledge and learning, and it also needs to propose an explanation of how the process of learning actually unfolds. Obviously, it would be impossible for us to go into all these issues in detail, as we would have to take into account centuries of research in philosophy, psychology, education, and so on. Our approach has therefore been to adopt a high level of abstraction that excludes a lot of detail (which would obviously be very relevant for other purposes) yet still allows us to lay the foundations for an unambiguous language of collective learning.

Of course, the model proposes a set of constructs whose definitions may not satisfy everybody. To the extent that the model is a proposal, any such definitions will have to be tested in the future. Again, though, the purpose of these definitions is not to provide "definitive" definitions, but to have a working framework and language that will allow us to talk unambiguously about knowledge and learning, both individual and collective.

II. Model boundaries

In order to keep the model as simple as possible, several decisions have been made with respect to what its boundaries should be. The following are specially relevant:

1. The model is centered around problem solving. Thus, knowledge is viewed as something useful for problem solving, and learning is assumed to increase the problem-solving potential of an individual or group. The definition of a problem, though, is general enough to include in learning almost anything that intuitively could be considered as such.

2. As far as possible, the model considers not action, but action plans (to solve problems) and how to design them. This avoids the need for explicit consideration of behavior and the associated details. However, in a few specific situations we have to deal with action; in these cases we try to limit it to situations where it is strictly necessary for our purposes.

3. One way of acquiring knowledge is, of course, by observing and perceiving the environment through certain "lenses". The model says nothing about these lenses or how they function; in fact, as far as possible, knowledge is assumed to be already "perceived" and "internalized" by individuals. Thus, the model does not deal with perception or interpretation mechanisms.

4. Another way of generating new knowledge is via reflection by an individual. To keep things simple, the model does not say anything about how reflection takes place or how it is "guided". In particular, the model deals with a specific kind of individual knowledge that we call "preference" and that is used to evaluate perceived states of affairs in the environment, resulting in judgments of "satisfactory" or "unsatisfactory". Individuals are assumed to have different "preference schemes", but the model says very little about how the individual chooses to use one preference rather than another in a particular situation. Thus, nothing is said, for example, about what is considered to be a "good" preference scheme, or how good schemes can be developed (see Pérez López, 1991; 1993).

5. Finally, no attempt is made to distinguish between "collective" and "organizational". We assume that "organizational" is a kind of "collective", and thus anything that is said about the latter can also be said about the former. Carefully defining "organization" and "organizational" so as to be able to extend model constructs and implications to the organizational context is at this point seen as an area where further work is needed.

III. The Model. Basic definitions

The model is presented below as a series of definitions, referring to concepts that interrelate and "function" in a certain manner, thus implying dynamics (in particular, problem solving and learning dynamics). Underlined words indicate undefined concepts that are defined a bit later on.

1. Knowledge Agent (KA)

1.1. An element capable of *designing an action plan for problem solving*: a process of knowledge creation/interpretation that basically compares a "current state of affairs" with a "future state of affairs" in the environment, presumably resulting from an action, and chooses the "best" action by evaluating and comparing "foreseeable future states of affairs" according to some kind of "preference structure" –a kind of knowledge. Agents have "individual memories" where "individual knowledge" (accessible in principle only to the corresponding agent, who can make it available or accessible to other agents either directly or through knowledge repositories) is stored away.

Refs.: Shrivastava (1983); Hedlund (1994); Tapscott (1996); Baek, Liebowitz, et al. (1997).

2. KA's knowledge-related capabilities (a KA might have other capabilities which, in particular, may be used in action plans)

2.1. A KA is capable of doing certain "knowledge processing" through the following kinds of capabilities (each agent has its own capabilities, to a higher or lower degree, usable exclusively by itself): Reflecting; Conceiving / Imaging; Organizing / Structuring knowledge; Deducing logically; Generalizing; Proving; Evaluating; Comparing; Choosing (among preference structures and among action alternatives for problem solving); Encoding / Decoding knowledge structures; Observing the environment.

Note: Much of the model constructs and dynamics can be understood assuming that these capabilities are constant over time; however, the capabilities can also be seen as something that can be improved (for example in terms of effectiveness), thus giving rise to learning, without changing the basic characteristics of the model. (An alternative view –see #5 below– would consider capability improvement as the result of improvement in related knowledge structures, e.g. mental models).

Refs.: Huber (1991).

3. Knowledge (individual)

3.1. Any information useful to a KA for the purpose of designing an action plan to solve a problem. Thus, it must "make sense" to a KA (for example in the context of a mental model). It can be stored in knowledge repositories or in KAs' memories, from where KAs can retrieve it.

Refs.: Duncan and Weiss (1979); Kogut and Zander (1992); Nonaka (1995); Davenport and Prusak (1998).

4. Types of knowledge

4.1. *Embodied* (contained in tools, processes or products); *encultured* or *embedded* (in individual or organizational routines; socially constructed; informal); *embrained* (non-conscious, difficult to articulate, personal); *encoded* (fully articulated by signs and symbols, easy to store away and transfer).

Refs.: Zuboff (1988); Collins (1993); Blackler (1995); Sieber (1998).

5. Knowledge structures

5.1. A collection of interrelated pieces of knowledge (maybe of different types) that makes special sense to a KA or collection of KAs. "Makes special sense" here means that the KA(s) know how to treat the structure, in order to apply knowledge-related capabilities to it, in a more "compact" ("effective" or "efficient"?) way than it would the individual pieces of knowledge. In particular, knowledge structures can be effective for observing and perceiving the environment in different ways, or for designing action plans, as they may constitute the skeletons of problem-solving approaches, for example.

Refs.: Schank and Abelson (1977); Lam (1997); Zhu, Prietula, et al. (1997) http://robin.tamucc.edu/~leasure/class/cosc5320/resources/ils-learn-by-doing.html

6. KA's memory

6.1. A knowledge storage area accessible to an individual KA that can hold knowledge structures made up of any type of knowledge pieces. Its degree of accessibility to the KA depends on each knowledge structure stored in it. In particular, knowledge structures stored in memories tend to decay in terms of accessibility (and thus usability by the KA) the less they are used in problem-solving activities.

Refs.: Cohen (1991); Singley and Anderson (1989); Levitt and March (1988); Walsh and Ungson (1991); Kim (1993); Lukas, Hult, et al. (1996); *The Economist* (1998).

7. Knowledge repository

7.1. An *encoded* knowledge storage area external to KAs, where knowledge can be stored or accessed and retrieved by any KA familiar with the "encoding language" used.

Refs.: Stear and Wecksell (1997); Anthes (1998); Tobin (1998).

8. Mental models

8.1. Individual, normally embrained or embedded knowledge structures that enhance the effectiveness of the capabilities of a KA. Thus, they are stored in KAs' memories individually. However, some of them can be encoded and thus externalized, transmitted, stored in repositories and shared by different KAs.

Refs.: Kim (1993); Nonaka (1994); Preece, Rogers, et al. (1994); Vandenbosh and Higgins (1996); Carley (1997); Miller, L. C., & Read, S. J. (1991).

9. Preference (always individual)

9.1. A kind of (multidimensional) knowledge structure used by KAs in action plan design (see #1, #13, #15). A KA may have several different preference structures, but only one of them will govern his action planning at any given time. Which preference structure "triggers" and thus becomes "active" may depend on a variety of circumstances (e.g. whether the KA is in the presence of –a certain number of– other KAs of a certain type, whether the KA perceives a certain "context" in the environment, whether there is a prioritary preference that always overrides any other preference that is incompatible with it –like a "principles" preference– etc.). Often, preference structures are embedded or embrained (and thus stored in KAs' memories), but they can also be encoded (and then they can be externalized and stored in repositories).

Note: Again Pérez López (1991; 1993) has a lot to say here, in particular regarding what he calls the "effective", "efficient" and "consistent" dimensions along which an action plan should, in his view, be evaluated.

Refs.: Weick and Bougon (1986); Kogut and Zander (1996); Lyles, von Krogh, et al. (1996).

10. Autonomous KA

10.1. A KA capable of choosing which preference structure to use (i.e. to make "active") at any given moment, or even of creating new preferences by reflection (e.g. I am playing chess with my son, and I decide that I will lose in order to keep his interest on the game). How or for what reasons a KA may change its preference lies beyond the scope of this model.

Note: Pérez López (1991; 1993) discusses this type of capability, and uses it to distinguish between different types of "agents".

11. Dependent KA

11.1. A KA whose "active" preference can only be changed by another, autonomous, KA through a knowledge transfer activity (which implies that the knowledge must first be externalized and encoded). In this sense, a dependent KA is "programmed" through encoded knowledge, and so too is its action planning capability. Thus, dependent KAs do not have the capability of choosing among preference structures (see #2).

12. Problem (individual)

12.1. A "state of affairs" (perceived) in the environment which is evaluated as "unsatisfactory" by a KA according to its currently active preference. (Note that this definition of a problem involves specifying the preference structure according to which the state of affairs in the environment is evaluated as "unsatisfactory").

Refs.: Pérez López (1991); Newell and Simon (1972); Argyris (1977).

13. Action plan (individual)

13.1. A knowledge structure that indicates how a KA's capabilities should be used to solve a particular problem, i.e. to change the KA's evaluation of the current state of affairs from unsatisfactory to satisfactory according to the KA's active preference during problem solving. Thus, an action plan includes a "control structure" that specifies how the KA's capabilities are to be combined to solve the problem. This "control structure" is very likely to be referred (linked in some way) to one or more of the KA's mental models, as a way for the KA to "understand", "justify", "make sense of" or even "improve the efficiency and effectiveness of" the action plan. To the extent that an individual action plan is encoded, it can be externalized, stored in repositories and accessed and used by other KAs.

Notes: 1. Depending on the preference structure employed, the emphasis placed on different aspects of the desired solution will vary. (Pérez López (1991; 1993), for example, would talk about an action plan being more or less "effective", "efficient" or "consistent".)

2. Since an individual action plan is always designed to tackle a particular problem as perceived and evaluated by a KA using a specific preference, it may not be useful for other KAs that perceive or evaluate the problem differently –or even for the original KA if there are changes in its relevant preference structures. In order to avoid confusion when a plan is put into effect, it is advisable to specify, as part of the plan, under which preference(s) it solves the problem. This is often not done in real life, creating all sorts of pitfalls.

14. Types of problems

Structured: A problem for which a KA already "knows" of an appropriate action plan that needs no further adaptation and can be applied right away, merely by retrieving it from where it is stored.

Unstructured: A problem for which a KA does not know of a preexisting action plan that will solve it. It is not that the KA has not faced the problem before; it might have faced it and not solved it, or only partially solved it –so that relevant knowledge about what was done on those earlier occasions may be stored away somewhere, but not as a complete action plan.

Refs.: Muñoz-Seca and Riverola (1997); Pérez López and San Roman (1973)

15. Problem solving (individual)

15.1. An action plan design activity by a KA the purpose of which is to solve a problem faced by the KA (according to the KA's current "active" preference). The activity depends on whether the problem is structured or not:

1. If the problem is structured, the corresponding action plan is retrieved from the KA's memory or from some repository and used to solve the problem. As was pointed out earlier, it may be necessary to check whether or not the action plan

in question still solves the problem, as the preference structure employed in its design might not be the same as the KA's currently active preference. (*Note:* If the existing action plan does not solve the problem anymore for this reason, it can be said that for the KA whose preference has changed the problem has become unstructured).

2. If the problem is unstructured, no predefined action plan is called upon; rather, the process consists of trying to reduce dissatisfaction by applying existing or new action plans to the current state of affairs and evaluating the resulting state according to the KA's active preference. Note that when we say "new action plans" we imply the creation of new pieces of knowledge (e.g. through reflection), or a new combination of existing pieces of knowledge of any type, including some deriving from other KAs via knowledge repositories (and thus via encoding).

Refs.: Isaacs (1993); Simon (1991)

16. Learning (individual)

16.1. Knowledge change or accumulation, either in the KA's memory or in repositories accessible to the KA, that makes the KA capable, during problem solving, of producing more "choosable" action plans than before in response to a problem. The change or accumulation may be the result of access to knowledge repositories and the corresponding transfer of knowledge –or merely the setting of appropriate "pointers" for future use; of reflection on the part of an autonomous KA; of knowledge interchange among KAs; or of registering the fact that during a problem-solving process (individual or collective) certain approaches involving particular knowledge structures –e.g. mental models– seemed to be more "productive" or "effective" than others. As an interesting implication, note that, according to this definition, a change in a KA's preference structure or triggering conditions may be enough to produce learning. Note also that dependent KAs may learn according to this definition.

Note: Learning as a consequence of changing a KA's preference (i.e. changing only the evaluation of a particular state of affairs so that it is no longer "classified" as a problem) is not a contradiction: One can "learn to live with" a problem, or "realize that what seemed a problem is not in fact a problem, as some aspects of it are very satisfactory once detected and evaluated".

Refs.: Duncan and Weiss (1979); Hedberg (1981); Cohen (1991); Simon (1991); Kim (1993).

17. Single loop learning (individual)

Note**:** *This construct is not strictly necessary for the completeness of the present version of the model, but it is included to give the reader an opportunity to check the model against a well established concept.*

17.1. Learning stemming from changes in any knowledge structure accessible to a KA (for example in action plans, which may become more efficient) other than the KA's mental models, preference structures and associated triggering conditions.

Refs.: Argyris and Schön (1978); Argyris (1993); Romme and Dillen (1997)

18. Double loop learning (individual)

Note: *This construct is not strictly necessary for the completeness of the present version of the model, but it is included to give the reader an opportunity to check the model against a well established concept.*

18.1. Learning stemming from changes in a KA's mental models, preference structures and associated triggering conditions.

Refs.: Argyris and Schön (1978); Argyris (1993)

19. Unlearning (individual)

19.1. Effective "elimination" of knowledge accessible to a KA, so that it is no longer considered in action plan design, making the KA less capable of producing effective action plans than before when faced with a problem. This may come about through "forgetting" (memory decay due to lack of use of pieces of knowledge), but also through changes in the KA's preference structures or their triggering conditions: such changes can result in certain action plans no longer being chosen in problem solving if the (new) active preference evaluates them as non-productive. Changes of this kind in a KA's preference can be the result of reflection, but also of organizational (collective) learning.

Refs.: Hedberg (1981); Magrath (1997).

20. Collective problem

20.1. A "state of affairs" (perceived) in the environment which is evaluated as "unsatisfactory" by a group of KAs, according to their individual active preferences. The "unsatisfactory" evaluation need not be shared (or arrived at through the same preference structure) by all the KAs in the group. The conditions for a state of affairs to be considered "unsatisfactory to the group" may vary: If there is a clear group leader, the leader's preference may define group satisfaction; most likely, though, there will be some kind of consensus or agreement "rule" that defines collective satisfaction or non-satisfaction in the above sense. Note that according to this definition of a collective problem, changing the consensus rule can be a solution. Note also that a problem-solving attempt may be successful even if it changes the evaluation to "satisfactory" for only some of the KAs in the group. Like individual problems, collective problems can be structured or unstructured.

Refs.: Weick and Bougon (1986); Kogut and Zander (1996); Lyles, von Krogh, et al. (1996).

21. Collective knowledge (structures)

21.1. Any knowledge or knowledge structure that is useful to a group of KAs for the purpose of solving a collective problem. Thus, it must “make sense” to the KAs in the group (for example in the context of the KAs’ mental models). It can be stored in KAs’ memories or (if previously encoded) in knowledge repositories, from where KAs can retrieve it. It is important to note that:

1. A collective knowledge structure may be made up of a series of heterogeneous knowledge “pieces”. In particular, there may be encoded and non-encoded pieces of knowledge. If all the pieces are encoded, the collective knowledge structure can be stored in a repository from where any KA, particularly group members, can access and use it. If not, the knowledge structure is the result of co-ordinated activities involving members of the group (e.g. during problem solving) and is thus contingent on particular group members.

2. A collective knowledge structure of particular interest is a collective action plan.

Refs.: Weick and Bougon (1986); D’Andrea-O’Brien and Buono (1996); Lyles, von Krogh, et al. (1996); van de Vliet (1997); Tobin (1998).

22. Collective action plan

22.1. A collective knowledge structure indicating how the capabilities of a group of KAs’ should be used to solve a collective problem. (Note that since the definition of a collective problem is subject to the “consensus rule”, this same rule must be used to check whether an action plan actually solves the problem or not). Thus, a collective action plan includes a “control structure” that specifies how the KAs’ capabilities are to be combined to solve the problem. This “control structure” is very likely to be referred (linked in some way) to one or more of the KAs’ mental models (individual to the extent that they are not encoded), as a way for each KA to “understand”, “justify” or “make sense of” the action plan. Collective action plans have a series of characteristics that are worth noting:

1. To the extent that the capabilities used in the plan are “non-encoded” (because they are supposed to be exercised on embrained or embedded knowledge belonging to individual KAs, or because they themselves are embodied), the action plan can only indicate how and when which KA in the group should exercise them (which is something that can perhaps be encoded); but the “complete” plan cannot be encoded in the sense of being put into a form in which it can be stored away in a repository for later use by *a different* group of KAs. Note that this implication of the model contradicts certain aspects of the learning process as proposed by Nonaka (1994), in whose “socialization” step knowledge is externalized, so that, according to this model, it ought to be encoded.

2. When a collective action plan is actually put in effect, the relevant capabilities of any given KA in the group will be exercised according to the plan only if that KA’s current preference permits it (i.e. only if the KA evaluates the expected state of affairs after using the capability as “satisfactory” or “acceptable”, according to its active preference).

3. Regarding which active preference each KA will use when following a collective action plan, it may be that the mere presence of a group of KAs will trigger an "appropriate" preference in each individual KA (see #24). This can lead to a "conflict of interests" in some of the KAs in the group, if the triggered preference is strongly in conflict with other "competing" preference structures.

4. The "control structure" of a collective action plan is more complicated than its counterpart at the individual level, as it specifies not only when capabilities are to be exercised, but also by which KA in the group. Thus, it has a "coordination" component that is not needed in individual action plans.

Refs.: Nonaka (1994).

23. Collective problem solving

23.1. An action plan design activity by a group of KAs whose purpose is to solve a collective problem as defined above (i.e. to improve an unsatisfactory state of affairs in the environment as perceived and evaluated, according to their active preferences, by each KA in the group, combining these preferences according to a consensus rule) and whose result is a collective action plan. The activity depends on whether the problem is structured or not:

1. If it is structured, the appropriate action plan is retrieved from the KAs' memories or from some repository and used to solve the problem (as in individual problem solving, it may be necessary to check the current active preferences of the KAs in the group).

2. If the problem is unstructured, no predefined action plan is called upon; rather, the process consists of trying to reduce dissatisfaction in the group of KAs by applying existing or new action plans to the current state of affairs and evaluating the resulting state according to the active preferences of each KA in the group and the consensus rule. Note, again, that when we say "new action plans" we imply the creation of new pieces of knowledge (e.g. through reflection on the part of some of the KAs), or a new combination of existing pieces of knowledge of any type, which can come from other KAs of any kind or from knowledge repositories (and thus via encoding).

3. In the preceding point, it should be emphasized that only encoded knowledge can be effectively shared among the KAs in the group. However, other types of knowledge may be effectively included in the action plan simply by indicating that certain KAs in the group "know" how to "do" something useful (albeit un-encodable) in the context of the problem-solving process, and that they should do (or try to do) it at a certain stage in the problem-solving process. This can be done quite easily if an appropriate language is available to refer to KAs' capabilities. Thus, only the control structure needs to be shareable.

4. An important part of the "control structure" is the coordination component. To the extent that it can be encoded, there is no problem in sharing it among the KAs in the group when an action plan is put into effect. Still, some parts of the coordination component can be collectively embodied or embedded (e.g.

when, as a result of practice, a number of KAs have developed an understanding among them that makes it possible to call upon their joint action as a block and include it as such in the coordination component of the control structure). In this latter case, though, the block of coordinated KAs must be treated as a single unit for all practical purposes. Note that this poses a problem of effective unlearning when one of the members leaves the group.

5. Another important aspect of collective problem solving has to do with the individual KAs' preference structures that are used in the process of deciding which capabilities to include in the action plan. Remember that, even though the individual preferences used in the evaluation need not be the same for all group members, the action plan has to result in a state of affairs that is rated "satisfactory" by as many KAs in the group as are required by the consensus rule. The individual preferences, though not all the same, can be made active by a "group-dependent triggering condition" of the following type: "whenever a certain number of a certain type of KAs are present, the active preference will be such and such" (a sort of "critical mass" concept). Through such a mechanism an action plan can be "group-personalized" or "group-sensitive" in the sense that if it is not put into effect in a certain environment it won't work –because the appropriate individual preferences won't trigger and some KAs will therefore not be willing to exercise the capabilities they are supposed to.

6. Note also that what is said in point 5 above implies that changes in the preference structure or triggering conditions of an individual KA, or a small number of KAs, can render a previously successful collective action plan ineffective (see also #24 and #25).

Refs.: http://www.santafe.edu/
Cohen (1991); Garvin (1993)

24. Organizational (collective) learning

24.1. Knowledge change or accumulation, either in the memories of a group of KAs or in repositories accessible to them, that makes the group capable, during problem solving, of producing more "choosable" action plans than before in response to a collective problem. The change or accumulation may be the result of access to knowledge repositories and the corresponding knowledge transfer –or merely the setting of appropriate "pointers" for future use; of reflection on the part of autonomous KAs in the group; of (encoded) knowledge interchanges among KAs; or of registering the fact that during a problem-solving process certain approaches involving particular knowledge structures –e.g. mental models– seemed to be more "productive" or "effective" than others. As an interesting case, note that a change in *individual* KAs' preference structures or triggering conditions may be sufficient to produce learning. Note also that, according to this definition, a group of dependent KAs may learn. To summarize, collective learning may come about through:

1. <u>Changes in the triggering conditions of the preferences of some of the group members</u>, as a consequence of individual "conviction" that the new conditions are better for reasons that lie beyond the scope of this model. This may come about simply through reflection (about past problem-solving experiences, for

example –which, incidentally, could justify the development and deployment of a best practices data base); through practice (in problem solving, don't forget) followed by an act of reflection; or through some KAs' explicit efforts to "convince" other KAs in the group to change (for instance, by making them "think" –reflect– about the virtues of a particular action plan, maybe leading them by example). If some of the KAs in the group are dependent, changes can be "forced" on them by autonomous KAs, be they group members or not.

2. Changes in the preference structures of some of the group members. These changes may come about in basically the same ways as in point 1 above, although the change processes are radically different (i.e. in point 1, the KAs already have the preference structure; they do not have to be "convinced" to develop a new one as they do here; they just have to be convinced to *use* a particular preference instead of others under certain conditions).

3. Changes in the group's consensus rule. Note that the actual process leading to these changes might be embedded in a collective problem-solving activity.

4. Changes in the mental models of some of the individual KAs in the group.

5. Changes in the control or combination structure of action plans.

6. Changes in the coordination component of action plans among which to choose to solve the problem. To the extent that (part of) the coordination component cannot be encoded, such changes can only be enacted through practice, and the result is likely to be dependent on the individuals practicing together.

7. Changes in the actual capabilities used in action plans among which to choose to solve a problem. This implies basic individual capability development.

   Refs.: Duncan and Weiss (1979); Hedberg (1981); Nelson and Winter (1982); Shrivastava (1983); Fiol and Lyles (1985); Levitt and March (1988); Kim (1993)

25. Collective unlearning

25.1. Effective "elimination" of knowledge accessible to a group of KAs, so that it is no longer taken into consideration in collective action plan design, making the group less capable of producing effective action plans than before when faced with a collective problem. This may come about through "forgetting" (memory decay due to lack of use of pieces of knowledge) on the part of individual KAs, or through changes in the KAs' preference structures or the conditions under which a particular preference structure becomes active: such changes imply that certain action plans can no longer be chosen (can no longer generate agreement or consensus) in problem-solving activities because the currently active preferences are different from what they were. Changes of this sort in KAs' preferences can be the result of reflection, but also of organizational (collective) "learning". Note that this implies that a group unlearns basically through the learning and unlearning of its members, but not necessarily of *all* of its members.

IV. A glance at the dynamics implied by the model

The definitions in the preceding section give a rather static view of the proposed model. Although they include indications of how different model constructs interact with one another when put "into action", the resulting dynamics are not well described. This section focuses precisely on the dynamics issue, putting the model components to work and describing the resulting processes.

First, the individual learning process that results from the proposed model is explored, starting with problem identification, then moving on to problem solving, and showing how individual learning results from individual problem-solving activities. Some problem-solving aspects relevant for learning are pointed out in passing.

A similar exercise is then done with collective learning, pointing out some of the very distinctive features of the resulting process. Of special interest are the role of the consensus rule, the relevance of knowledge sharing and how it can take place, and the importance of the coordination scheme for implementation.

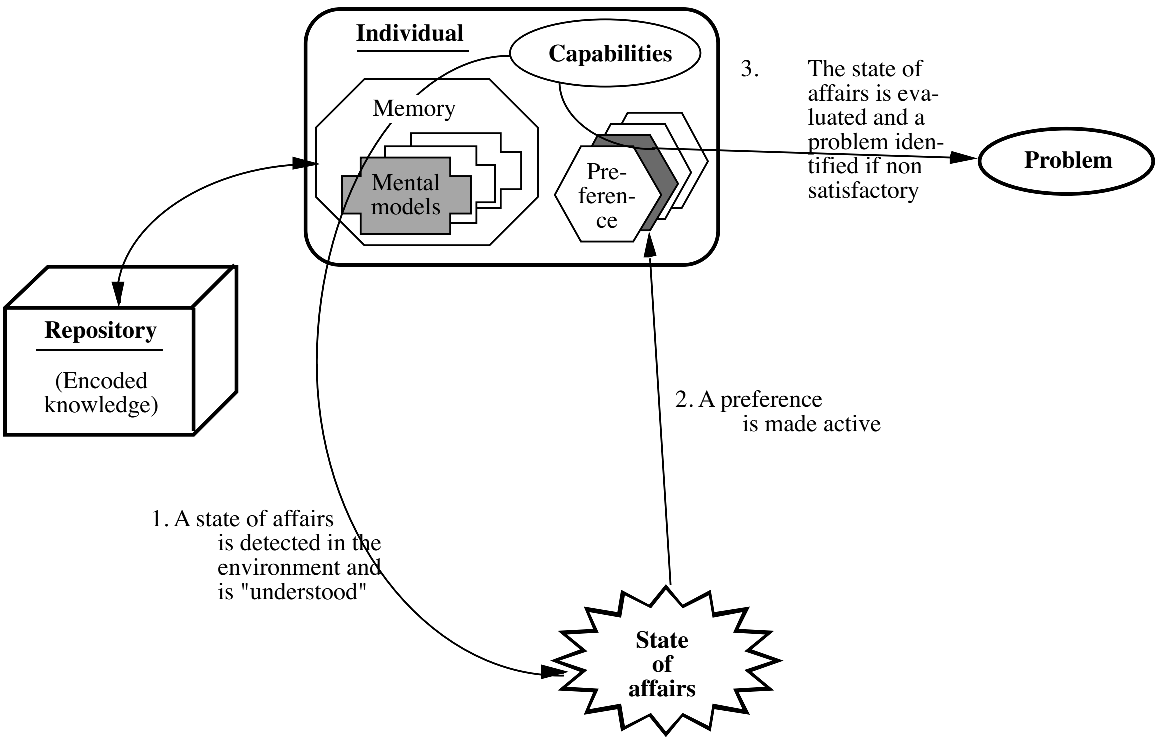
An effort is also made to describe each process schematically.

1. Individual learning

1.1. Identifying an individual problem

The process of identifying an individual problem, i.e. detecting a "state of affairs" (perceived) in the environment that an individual evaluates as "unsatisfactory" according to his currently active preference, can be depicted schematically as shown in Figure 1 below.

Figure 1. Individual problem identification process



The process starts with the detection of a certain state of affairs in the environment which is “understood” by the individual through both his internal knowledge structures and mental models, along with other relevant (encoded) knowledge from external knowledge repositories. The state of affairs is then evaluated using the “active preference scheme” triggered by the characteristics of the state of affairs. If the state of affairs is evaluated as unsatisfactory, it is identified as a problem.

1.2. Individual problem solving and learning

As proposed in the preceding section, **individual problem solving** consists of designing an action plan, i.e. a knowledge structure that indicates how a KA’s capabilities should be used to solve an individual problem. This may come about in three ways:

1. Retrieve an action plan that is known to “work” (i.e. solve the –structured, see #14 in section III– problem) from the individual’s memory or from a knowledge repository, and use it.

2. Combine existing pieces of knowledge or knowledge structures to produce the required action plan. This may include pieces of external knowledge retrieved from a knowledge repository.

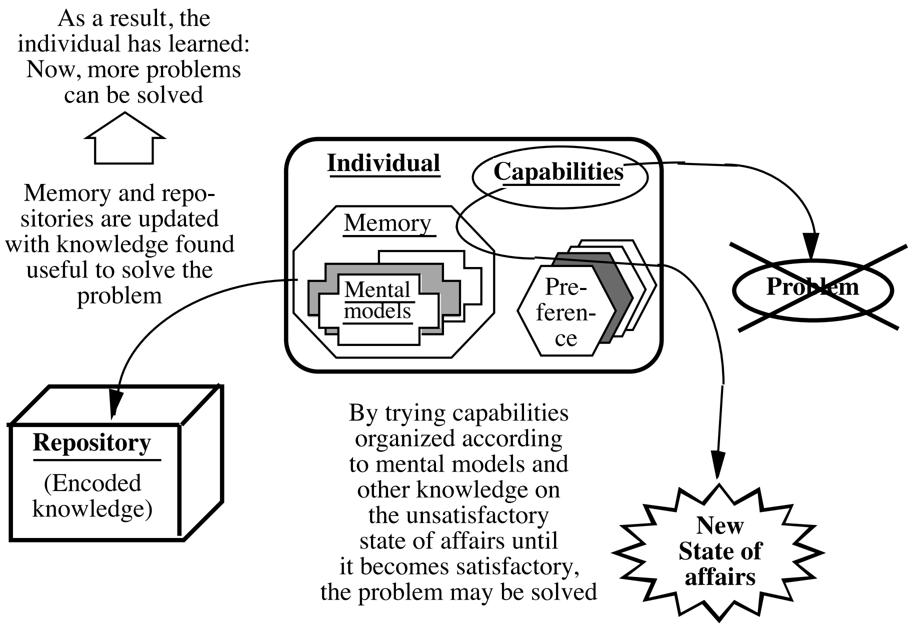
3. Create new pieces of knowledge (e.g. through reflection) and include them in the action plan.

Step 1 of the above problem-solving process may lead to individual learning (see #16 in section III) because the retrieved action plan will become more accessible from memory for future use (see #6, preceding section).

Steps 2 and 3 can also lead to individual learning, as new knowledge structures become accessible to the individual for future problem-solving activities (e.g. a different mental model or a change in the individual's preference structures or their triggering conditions).

This process can also be depicted schematically, as in Figure 2.

Figure 2. Individual problem solving and learning

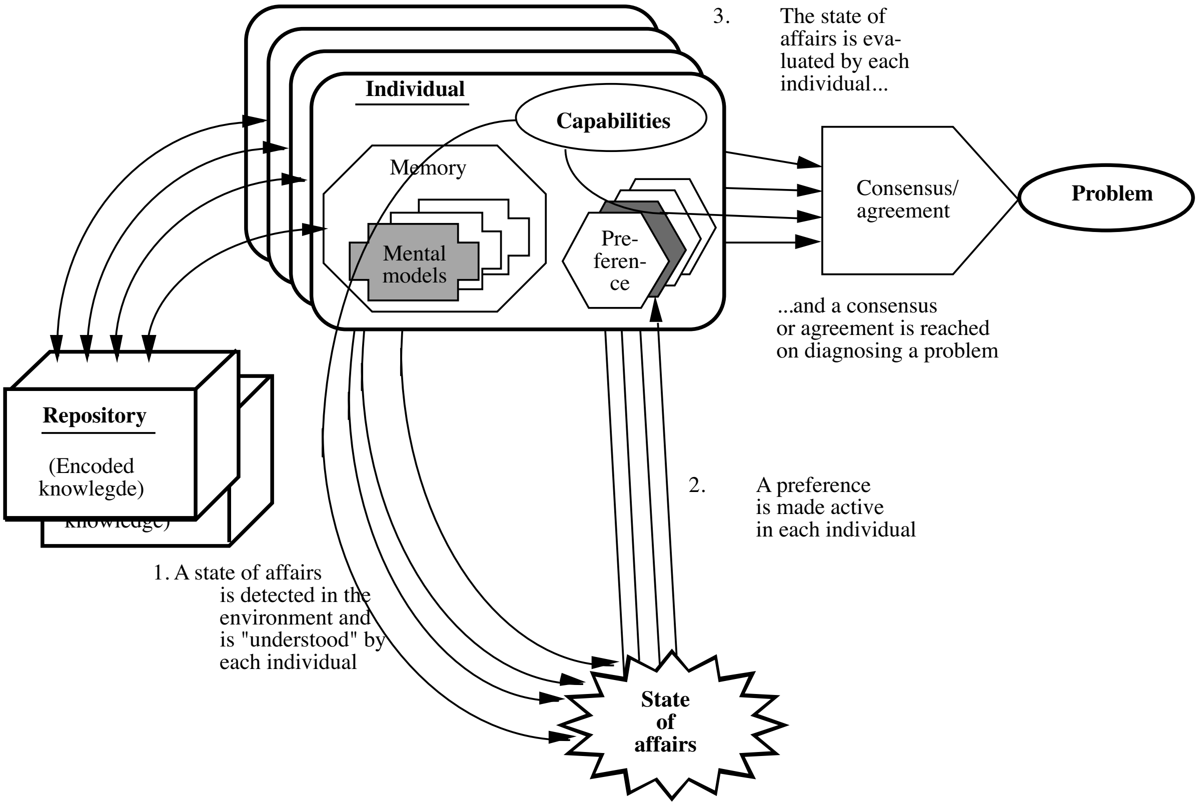


2. Collective learning

2.1 Identifying a collective problem

A **collective problem** was defined as a "state of affairs" (perceived) in the environment which is evaluated as "unsatisfactory" by a group of individuals according to their current preference schemes and a consensus rule. The process of identifying such a collective problem can be represented as in Figure 3.

Figure 3. Collective problem identification process



The process starts with the detection of a certain state of affairs in the environment which is “understood” by a group of individuals through knowledge structures contained in memories accessible to them, including their mental models. The state of affairs is then evaluated; each group member evaluates it using his own active preference, which has been triggered in a way that is not independent of the perceived state of affairs. The resulting evaluations need not all be the same, nor need they all derive from the same preference structure. The conditions for the resulting collective evaluation to be that the state of affairs is “unsatisfactory to the group” may vary: If there is a clear group leader, his preference may define group satisfaction; most likely, though, it will be through some kind of “consensus” or “agreement” that the group “declares” the situation satisfactory or not, combining the individual evaluations in some group- and even situation-dependent way.

2.2 Collective problem solving and learning

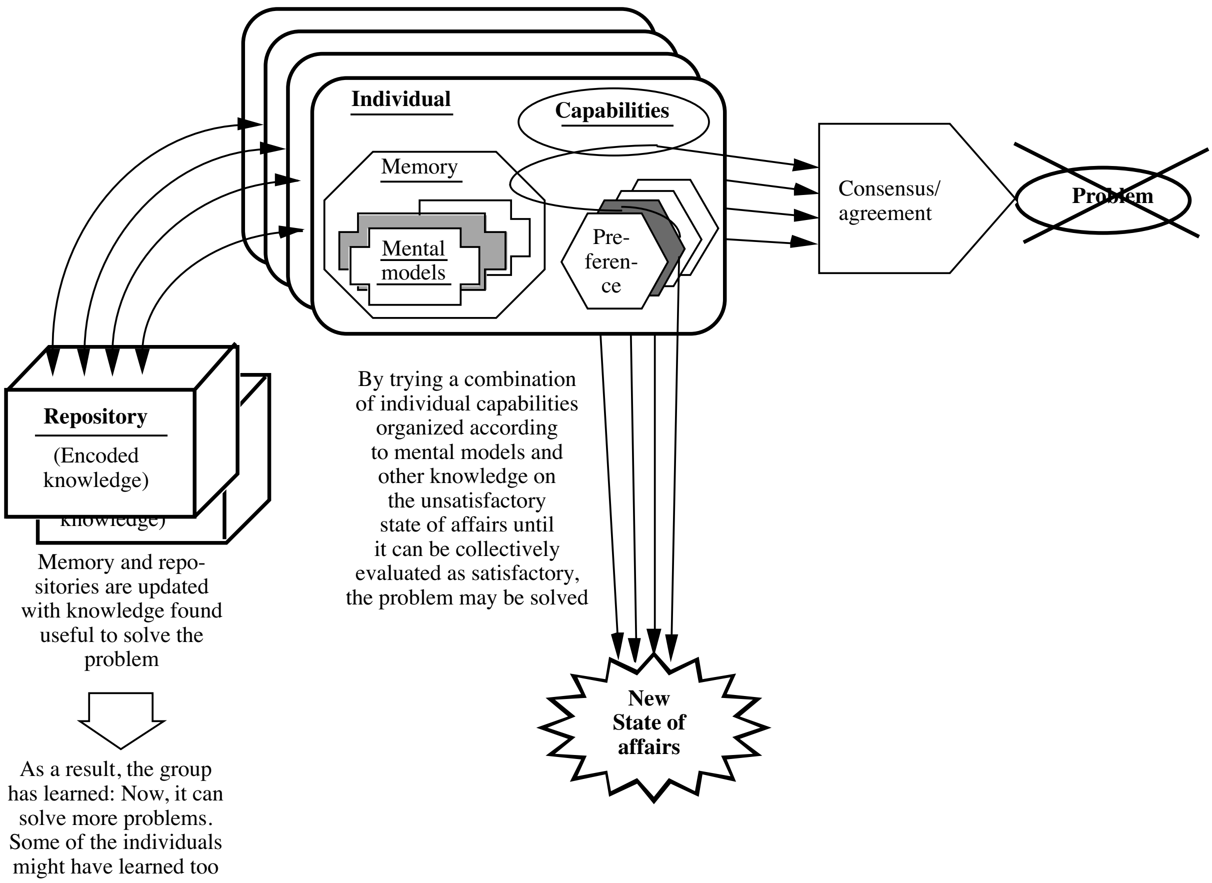
Collective problem solving consists of a group of KAs designing an action plan. The result is a knowledge structure that indicates how one or more KAs’ capabilities should be used to solve the problem (including an appropriate control structure and, in particular, a coordination scheme). There are various possibilities for designing such an action plan (see also #23 in section III):

1. (Structured problem) An appropriate action plan is retrieved from the KAs’ memories or some repository and used to solve the problem

2. If no appropriate action plan exists (i.e. the problem is unstructured), there begins a process that seeks to reduce dissatisfaction within the group by applying existing or new action plans to the current state of affairs and evaluating the resulting state according to the active preference of each KA in the group and the active consensus rule. This may be done, as in the case of individual problem solving, by: (a) combining existing knowledge pieces or structures, or (b) creating new knowledge using some basic capability of some of the KAs.

Figure 4 below is an attempt to depict how a collective problem-solving process unfolds.

Figure 4. Collective problem solving and learning



Alternative 1 above may lead to collective learning (see #23 in section III) because the retrieved action plan will become more accessible from memory for future use (see #6, preceding section).

Alternative 2 can also lead to collective learning, as new knowledge structures (e.g. a different mental model, or a change in individual preference structures or their triggering conditions, or a change in the group's consensus rule) become accessible to the group for future problem-solving activities.□

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