AN INTEGRATED IS FRAMEWORK FOR MANAGING INNOVATION

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Abstract

While the management of innovation is the most knowledge-intensive organizational process, its information technology support has received only fragmented attention. Addressing the collaborative nature of the innovation process, in this paper we present *Knowledge Breeder* and its associated problem-solving methodology (Group Model Building by Selection and Argumentation) as a framework for supporting the innovation process in its entirety by enabling the "breeding" of the innovation concept. The core of the framework is a systemic modelling formalism that allows data in different forms to be attached to and retrieved in all the phases of the innovation process. Collaboration is by means of a structured dialogue and is centred on the models and their information artefacts proposed by different participants. This increases the efficiency of decision-making while at the same time enhances knowledge elicitation and integration. In the paper, we present the structure and the characteristics of our framework and we demonstrate its use through an example.

Keywords: innovation management, information technology collaboration, knowledge management.

An integrated IS framework for managing innovation

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1 Introduction

Innovation is a process where knowledgeable and creative people and organizations frame problems and select, integrate, and augment information to create understandings and answers (Teece, 2001). Although efficiently organized information cannot substitute tacit knowledge, understanding and learning, it can significantly enhance them. Hamel emphasizes the role of information technology not only for product or process innovation, but also for what he calls business concept innovation (Hamel, 2002). However, neither he, nor other authors specify the sort of information technology required for enhancing and supporting such a process. Clearly, innovation is a social process, but its complexity necessitates technologies and systems that go beyond simple idea-processing systems, document management systems, intranet and internet conferencing systems or web portals that have been proposed as innovation-supporting technologies.

A closer examination of the innovation process, from both the knowledge-based view of the firm and through the lens of the social dynamics of organizational decision-making, sketches the necessity of an integrated information system that explicitly addresses the interplay between social and knowledge processes. Innovation, as a decision-making process, is initiated from ideas which are the result of a scanning phase, followed by a strategy development phase, a resource requirements evaluation phase and, finally, an implementation feasibility assessment phase (Tidd et al. 1997). With the possible exception of scanning, all other phases involve many individuals, probably with diverse backgrounds, knowledge, skills and cognitive spheres. Decision making in all the above phases is a collaborative decision-making process that begins with an initial idea or proposal, continues with the exploration of alternative ideas and proposals, before it is focused on the exploitation of the most appropriate (and most promising) of them (Schwartz, 2003; Leonard and Sensiper, 2003). The interplay between social and knowledge processes results in the emergence of groups-within-groups. Apparently promising ideas or proposals attract a critical mass of supporters which argue in their favor. Other groups attract less support and more opinions against their ideas. In this manner, as social processes result in the formation of groups, knowledge is combined and clustered around specific ideas, solutions or views.

From the information technology point of view, it is clear that in addition to database and internet solutions for technology and market scanning, the above processes require collaboration-supporting systems that allow a rich expression and discussion of ideas/proposals, and technology to support the efficient storage and retrieval of codified knowledge, experimentation with ideas and potential solutions, as well as argumentation and conflict resolution. Systems implementing these technologies in isolation have been proposed and used in actual organizational settings. However, the innovation process has not been addressed in its entirety.

Starting from a design philosophy that embraces a processualist view of information management, we have developed an IS framework to support the innovation process.

What drove the development process was not how information should be stored and retrieved, but rather what activities are executed when knowledge workers use their knowledge. The glue that binds the different innovation activities and their related information technologies is a collaborative model building methodology and a systemic modelling formalism that allows data in different forms to be attached to and retrieved at all the phases of the innovation process. The formalism consists of seven parts: problem definition, causes of the problem, symptoms, solution, justification of solution with respect to the causes of the problem and its symptoms, evaluation of solution, and proposed actions. Solutions can become problems in the same or subsequent phases. The core of our framework is, *Knowledge Breeder*, a web-based system that supports a collaborative modelling methodology called *Group Model Building by Selection and Argumentation* (G-MoBSA) (Adamides and Karacapilidis, 2003) which is initiated by the expression of an idea or proposal in the form of a model instantiation, usually after the scanning phase. The phases of the innovation process constitute problem resolution tasks (Leonard and Sensiper, 2003) where models are subject to argumentation by all the participants. The argumentative discourse and its conflict resolution rules are supported by formal argumentation procedures based on the logical propaedeutic of the Erlangen school (vam Eemeren et al. 1996). The evolution of the model drives the evolution of the innovation concept and provides the context for attracting the related knowledge and data sources. More than one model can be under consideration at the same time, and participants can argue for or against its elements. The results of a decision-support system, a document management system, or a simulation tool (spreadsheet, geometrical models, system dynamics models, etc.) can be attached to the model and further exploited at a later stage.

2 Innovation as a knowledge management process

For the design of an Information Systems platform to support innovation, it is necessary to understand innovation as a core business process. The holding view of the structure and function of this process with respect to the organizational structure has evolved over the years, from the purely sequential linear models of “technology push” (from R&D to the market) and “market pull” (from market to R&D) to a coupling and matching process where interaction is the critical element (Rothwell, 1992) (figure 1). Current models see innovation as a continuous multi-actor process that requires high levels of integration at both the inter- and intra-firm levels. In such a perspective, information technology in the form of collaboration-supporting systems can enhance systemic integration and networking, support flexible and customized response to internal and external signals, as well as coordinate and integrate different knowledge sources.

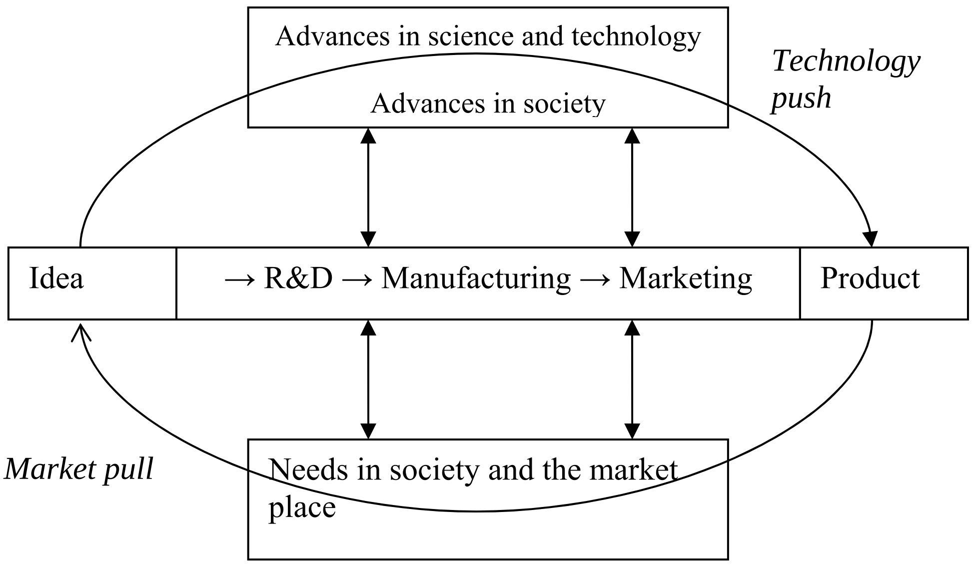

Fig. 1. Interactive model of innovation (source: Trott (2002))

Individuals from diverse functions are involved in different innovation activities which can be organized in four phases, which are not necessarily executed in a linear fashion and are usually iterated. In the scanning phase, ideas on exploiting internal or external opportunities placed for consideration. Discussion, filtering and structuring for decision making takes place through organizational routines and procedures. In the strategy development phase that follows the organization is concerned on what to do with the innovation concepts developed in the previous phase. Three inputs to the phase are placed for consideration: the outputs of the previous phase, the internal technological assessment and the fit of the emerged innovation concept with the overall business. Once the strategy for the qualified concept has been decided, in the next phase the resources required for its implementation are considered. Dilemmas such as make or buy have to be resolved. Finally, in the implementation phase, the actual development activities (design, prototyping, testing, etc.) are examined for their feasibility.

From the knowledge management point of view, information and communication technologies can act as a medium through which different organizational structures are formed to combine efficiently unconnected bodies of knowledge, or to combine existing knowledge in novel ways. The outcome of these combinations is organizational learning which augments the ability of the form to develop innovative products and processes making sense and responding to its own technological and organizational capabilities, as well as to existing and emerging market needs.

The importance of the involvement of diverse knowledge sources in innovative product and process development has been greatly emphasized. It has been shown that the use of cross-functional teams with diverse occupational and intellectual backgrounds increases the likelihood of combining knowledge in novel ways (Leonard, 1996). In such teams, the amount and variety of information available to members is increased, enabling the proposal and evaluation of different design alternatives from a number of different perspectives (Brown and Eisenhardt, 1995). Moreover, in the modern multi-site enterprise, these teams are not only functionally diverse, but also spatially. This further emphasizes the role of IT as the enabler for the formation of virtual teams to execute the innovation process (Rad and Levin, 2003).

3 Information technology for collaboration and knowledge management

A series of systems (e.g. QUESTMAP, EUCLID, JANUS, SEPIA, SIBYL and BELVEDERE – for a brief review see Karacapilidis et al. 2003) has been already developed to support the capturing of decision rationale and argumentation for different types of user groups and application areas, including facets of the innovation process. Such systems address the needs of a user to interpret and reason about collective knowledge during a discussion. They provide a cognitive argumentation environment that stimulates discussion among participants, but lack or demonstrate poor decision making capabilities, in addition to exhibiting an "urgency" for the integration of the different perspectives into a single solution-concept, on which the whole discussion is focused. Another category concerns Web-based conferencing systems, such as AltaVista Forum Center, Open Meeting and NetForum. These exploit the platform-independent communication framework of the Web, as well as its associated facilities for data representation, transmission and access, and provide the means for discussion structuring. However, they only offer a collection of vaguely associated comments and lack consensus seeking and decision-making features. On the other hand, the decisive role of information technology in the form of simulation modelling has been widely emphasized (Schrage, 2000; Thomke, 2003). Various systems addressing activities that range from product geometrical modelling to project financial appraisal have been developed and used. However, their interoperability and the difficulty of embedment in collaborative processes is still an obstacle for their wider diffusion.

The shape of an information system is highly influenced by the philosophy of the design methodology adopted. The majority of design methodologies used are concerned with the speed and accuracy in the retrieval, calculation, communication and storage of the information resources. However, issues related to the social and knowledge processes need a more sophisticated and context-aware handling and are still to be addressed. Traditional IS approaches such as the life-cycle and the structured paradigm, or even Prototyping and Rapid Application Development, have been extremely criticized in that they do not provide a sound understanding of business processes and organizational change. To remedy this, new methodologies emphasizing what people do while communicating, how they create a common reality by means of language and how communication brings about the coordination of their activities have been proposed. These have been basically founded on the Language/Action perspective (Dignum et al., 1996) and the Speech Act Theory (Searle, 1969) and consider the utterance of various types of communicative actions as the backbone of the business process modelling. However, even the above methodologies fail to fully support the development of systems to aid group reasoning processes, encourage dialoguing and stimulate the exchange of knowledge. The proposed methodology and the system that implements it aim at overcoming the drawbacks of the above approaches.

4 The G-MoBSA methodology and the *Knowledge Breeder* environment

4.1 General features and process

G-MoBSA is essentially a systems methodology (Flood and Jackson, 1991) enriched with argumentation to provide the interaction mechanisms needed to make a structure (model) (Meyers and Seibold, 1989). The basic idea is that participants provide complete models/representations of the issue, as they understand it, with their proposed solutions supported by causal relationships, i.e. they express complete rationales for what they propose. Proposed models are the result of individual sense-making of the organization and its environment which includes the outcomes of previous stages in the innovation process. Models are subject to discussion and argumentation by all team members. Gradually, in addition to providing their own situation-solution models (positions), the other participants may enrich the existing models with further elements and/or links among the elements. The validity of each model is subject to argumentation at various levels (as a whole, in its supporting elements, or in specific links). As the validity of a model cannot be determined in a subjective manner, what can give a more objective indication is its defensibility, i.e. how well the proponent and other participants defend it.

The models proposed are shaped by the proponents' "appreciative systems" (Vickers, 1983). In the strategy formulation context, the structure of appreciative systems is influenced by the participants' own history and power status and maintained through their self-reference attribute. For Vickers, strategists develop policies by managing relationships through their appreciative systems, rather than trying to attain objectives. The proposed and discussed models are representations of such relationships. Consequently, the development of strategy becomes a subjective continuous learning and adjustment process of mental models (appreciative systems), rather than an one-off task performed on the basis of objective scientific foundations. To overcome the problem of knowledge-power distribution (Flood and Jackson, 1991), the implementation of Knowledge Breeder promotes the attachment of objective codified knowledge (in the form of fact-supporting data) to the models under consideration. Conflict resolution is through formal argumentation rules. In addition to collaborative model creation, argumentation is a social construction methodology that provides structure and outcome to dialoguing, thus placing group interaction at the centre of knowledge acquisition (Metcalfe, 2002). The defensibility of each model is determined as a guide of its validity, which leads to its eventual selection.

On the basis of his/her perception of the issue, each team member can construct and propose a model of the problem and its solution using the language of the problem-solution modelling formalism. As the participant has access to the whole set of models proposed, he/she may adjust his/her mental models and contribute to the construction of models accordingly. Both the model per se (completeness) and its defensibility (fact-supported argumentation) can change a participant's perception. At the same time, the participant seeks facts/information to further support his/her proposed model, which may have the indirect effect of reviewing his/her own perception and knowledge base. The same modification processes take place with respect to the mental models of the other participants. As a result, mental models are converging around specific models and some of the models attract more attention concentrating the argumentation on them. Normally, the model that is best supported by facts and attracts the favourable views of the community is finally selected. In this way, G-MoBSA aligns the model building process with the social dynamics of the team involved in the resolution of the issue (figure 2).

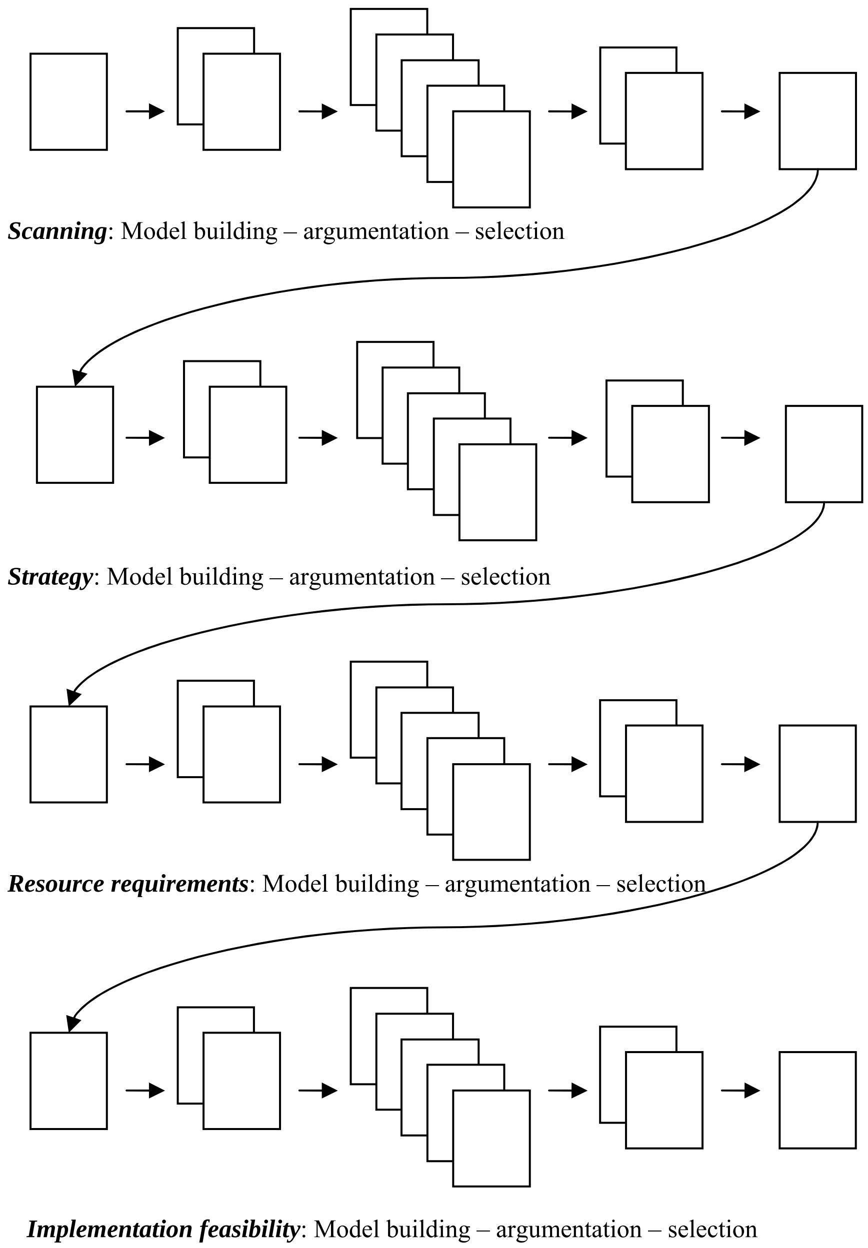

Fig. 2. Innovation management using the G-MoBSA methodology

In general, in a group modelling session, a group member participates in four distinct activities with respect to the model: construction of the model, presentation and understanding of the model, critique to the model and intervention on the model. Model construction is synonymous with the externalisation phase of knowledge construction (Nonaka and Takeuchi, 1995). The model construction activity involves an intensive interaction between the modeller's world and its knowledge base in one hand, and the context on the other. It is a process of knowledge transformation from more tacit to more codified forms. In trying to codify, pieces of knowledge are critically reviewed, associated and receive new meaning. The development of a model by a single participant allows him/her to organise his/her knowledge base and arguments in a more complete and consistent way. The construction of the model indirectly defines the space of possibilities that the participant sees and is a proposal for action. Model presentation and understanding result in the re-organisation of a participant's knowledge base. In trying to interpret another participant's model, someone either deletes elements and associations from its own knowledge, or strengthens his/her views by associating different facts and different (new) meanings. This is a more personal and tacit process (knowledge internalisation) compared to the critique and intervention activities that involve, as in model construction, externalisation of knowledge.

4.2 The G-MoBSA modelling formalism

Figure 3 shows the basic structure of the modelling formalism used in G-MoBSA. It consists of seven parts: problem definition, causes of the problem, symptoms, solution, justification of the solution with respect to the roots of the problem and its symptoms, evaluation of solution, and proposed actions.

In the problem definition, a participant's perception of what constitutes the problem is asserted. The causes-of-the-problem section provides participants with a template to answer the question "why this is the problem". The reasons that cause the problem can be described in a hierarchical cause-effect manner. Logical connections (e.g. "A AND B cause C") can be inserted and are used for argumentation and conflict resolution. In the symptoms section, the results of the existence of the problem (again, as they are seen through the specific participant's eyes) are defined in the same hierarchical cause-effect manner. In the solution proposal clause, the proposed solution is briefly defined, while justification provides the proponent with the means to argue why the proposed solution cures the causes of the problem and, directly or indirectly, eliminates its symptoms. Attached to the proposed solution is its evaluation, which allows the proponent to argue why the proposed solution is a feasible and effective one. Finally, the proponent can insert a set of proposed actions to justify his/her evaluation with respect to them.

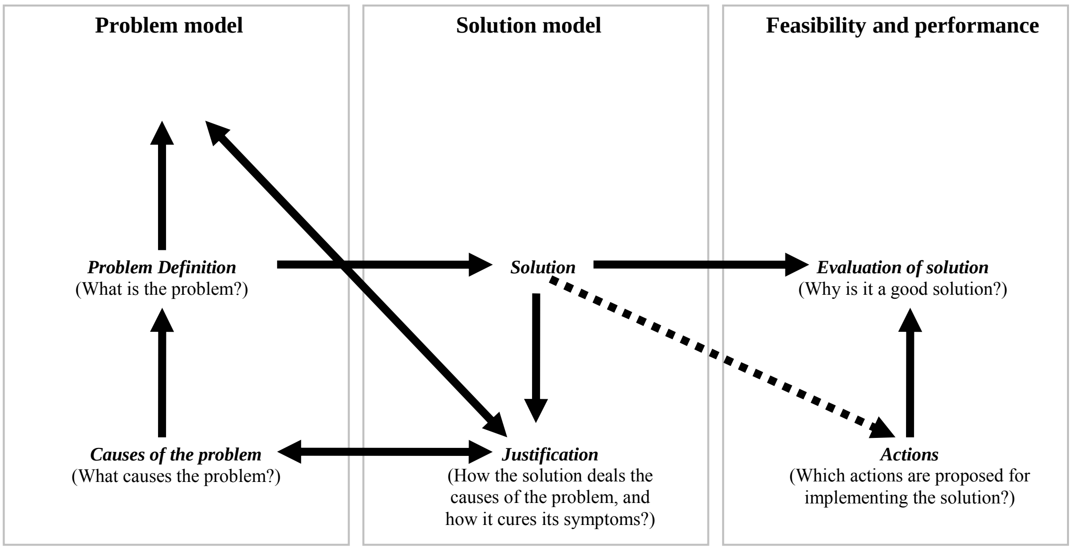

Fig. 3. The G-MoBSA modelling formalism

This modelling formalism provides the means for expressing complete arguments on what constitutes the problem, why this is the problem, and how the proposed solution cures it in the most suitable way for the company.

4.3 The argumentation schema

Although different argumentation schemata can be used, the current implementation of G-MoBSA relies on the logical propedeutic of the Erlangen school (van Eemeren et al., 1996). In our methodology, complete arguments are represented by means of simple statements related by logical connectives (operators). The logical connectives used are confined to: AND (conjunction), OR (disjunction), IF … THEN (implication) and NOT (negation). The argumentation schema provides the rules for conducting the dialogue among participants and resolving conflicts, i.e. it indicates which argument or clause holds and which is defeated.

More specifically, the starting rule indicates that the participant who asserts a complete model (thesis) is the proponent who starts the dialogue. Participants that defend elements of the model are the opponents, while participants that support statement are the supporters. In a specific dialogue instance, a supporter may become proponent as a different participant challenges his/her argument. There is no predefined priority rule as far as the assertion of positions is concerned. The general dialogue rule indicates that, at any instance, a proponent can attack one of the statements put forward by an opponent or defend himself/herself against an opponent's attack. The opponent, in turn, can attack the statement made by the proponent in a preceding move or defend himself/herself against the proponent's attack in the preceding move.

The structure of the models implies that the winning rules focus on combined statements (elementary statements connected by logical connectives), rather than on simple assertions. Consequently, ultimate victory results from the successful defence of elementary statements on which argumentation has been exercised. The specific winning rules are:

- If a node in the model is supported by two or more statements connected with the AND operator, then an opponent may argue against this statement by attacking the supporting elements individually. If the proponent of the model can defend the attacks on the supporting statements, the model is considered to be defensible (holds). Otherwise, this part of the model, including any reasoning based on it, is in doubt.

- If an argument is composed of two statements connected with an OR operator, then an opponent may attack the whole statement at once. The defender has two chances to defend the argument, corresponding to the two constituent parts of it (three if the argument constitutes of three statements, and so on). Depending on the outcome of the conflict (defended or not fully defended argument), the supported argument may be declared as defensible or in doubt.

- If a participant attacks an argument based on the implication relation, then he/she is obliged to provide either a different cause or a different effect/implication. This provides the main reason for supplying a different model of the problem and/or solution. The defender may defend the cause or the result of the implication.

- Finally, if the proponent of a negative thesis is challenged, the opponent has to assert that the argument holds. If the proponent succeeds in defending the negation, the argument is considered as defensible. Otherwise, it is in doubt.

4.4 Information technology support – The *Knowledge Breeder* environment

In G-MoBSA methodology, the different stages of the model building and selection process are not executed in a linear mode, but every time a member of the community interacts with the shared modelling space, the threat of the execution of the methodology moves there. This is facilitated through *Knowledge Breeder*, an IS framework operating on the web. The kernel of *Knowledge Breeder* is the model base that stores the models under discussion and models of terminated discussions. Any form of electronic information artefact can be attached to the model (documents, drawings, hypertext links, etc.) Models are stored hierarchically, on the basis of the hierarchy of the issues addressed. Managers can upload the current issues under consideration in which they are involved, see the current state of the dialogue and contribute accordingly. The inference engine of the tool determines the defensibility of each model, at any instance in the resolution process, by taking into account the structure of the model, the arguments placed and the argumentation rules.

The interface of *Knowledge Breeder* is in hyper-textual form with menus associated to the features provided and buttons serving folding and unfolding purposes. This results in easier asynchronous interaction (complex graphs are more difficult to be understood by participants involved in the discussion asynchronously). This was proved during the evaluation phase in a software company that develops simulation systems. The sample session described in the following section refers to the same company.

5 Managing the innovation process with *Knowledge Breeder*

In this section, we briefly present how *Knowledge Breeder* can be used in a specific issue resolution within the innovation process. It is clear that the G-MoBSA methodology supports a process that simultaneously considers both the external and the internal environment of the firm.

In the sample session presented, managers of the software company are engaged in a discussion over the evaluation of a product concept (a software tool to guide the modelling process in a simulation environment). Figure 4 shows the problem-solution model proposed by the company's CTO. In his view, "Limited subsequent growth" (the upper-level symptom) will be the result of the need to embrace "Cost-leadership strategies" (lower level symptom) which, in turn, will be caused by all the competitors offering products with the "Same product functionality" adding the "Same services" on their products (lower level symptoms). In his view, these will be the results/symptoms of the easily "Imitable technology" on which the product concept is based. For the CTO, the problem will be caused by the application of "Standard interface technology" AND "Standard communications technology". These constitute the principal causes of the problem. As a solution to the problem, he proposes a "New product concept: Agent-Based Simulation". He justifies his proposal by linking it to the causes of the problem ("It is a new scarce technology", which "refers to id: 1.c1, 1.c2"). In this way, the system infers that his model is complete, as far as the problem-solution relationship is concerned. To accomplish this task, *Knowledge Breeder* uses the structure of the proposed model and the implication relationships that hold between elements in succeeding levels. In the specific example, by having the proponent to indicate that the solution defies the clauses standard interface technology" and "Standard communications technology", the system infers that the problem does not exist any more, since the cause of technological imitability. In addition, in the Feasibility, Performance and Actions part of the model, the proponent provides reasons why he thinks this solution is a feasible and good one (e.g., "Existing distribution channels", "Maturing technology"). To make his evaluation more concrete, he indicates specific actions. For instance, he estimates and proposes to the company to "Hire 5 new software engineers" (which particularizes his conclusion that "Only few new experts are required"). He also indicates relationships holding among the elements of this part of the model. For instance, by providing the links "supports: 1.e3" to the appropriate statements ("Existing distribution channels" and "Only few new experts are required"), he further justifies his evaluation that the proposed product concept requires reasonable investment.

Knowledge Breeder provides to each participant interested in placing a model for consideration a template structured on the basis of the G-MoBSA modelling formalism. By selecting the specific model section, the system prompts for inputting model elements/statements. In turn, by selecting a statement, the user can input elements that further support it. By clicking on each statement, a proponent can provide additional information in a free-text form or through links to web pages and documents (this is achieved through a pop-up window). The construction of individual statements and their associations is facilitated through dynamic interfaces.

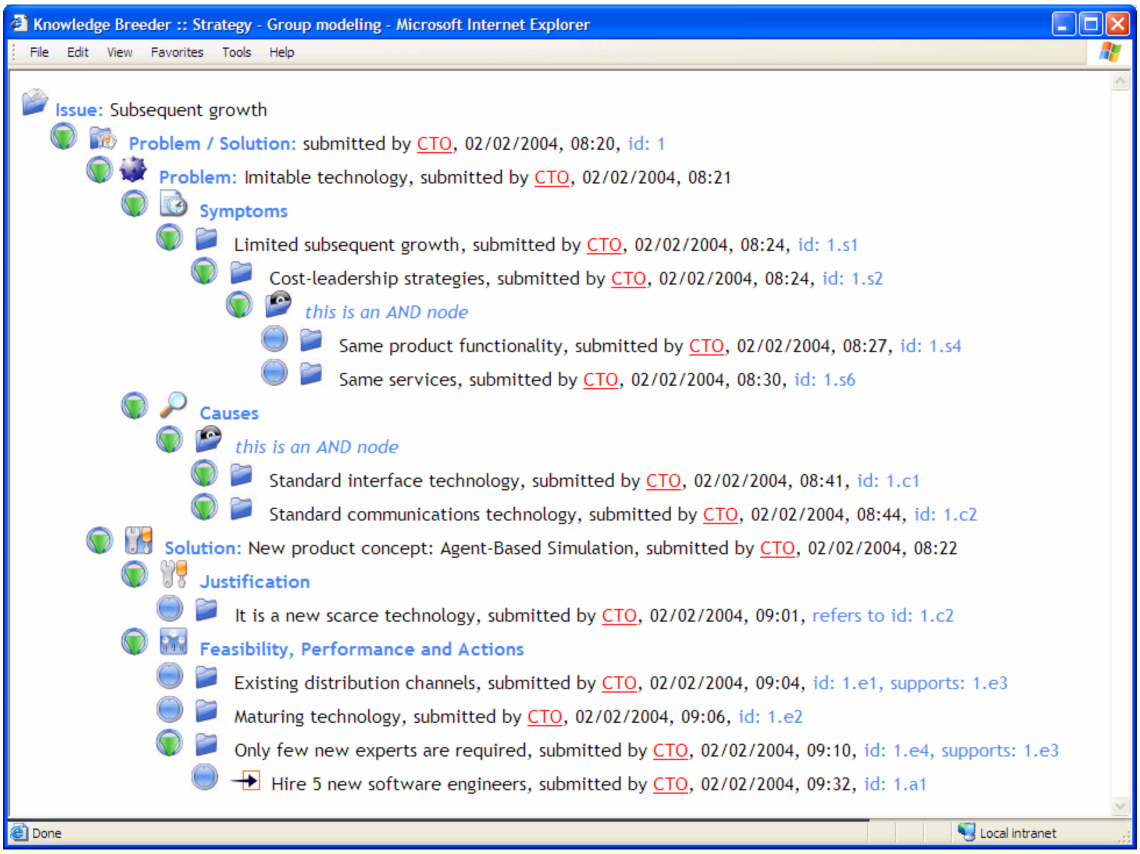

Fig.4. A complete argument (model) on an innovation concept

Figure 5 shows another instance of the same model, which includes additional arguments placed during the discussion. One can observe the agreeing and re-enforcing argument of the Services Manager with respect to the expected homogeneity in services ("All competitors can offer training, support hotline etc.") and the attacking argumentation of the Senior Project Manager that indirectly prompts participants to his own argumentation/model. This participant criticizes the model by first placing an additional element ("Not application specific") in the causes section, asserting that this is the principal reason of (the same) problem. In addition, he asserts that the symptom "Cost-leadership strategies" will also be the result of his view of the problem. Then, he argues that the proposed model's solution does not take this fact into account ("But what about applications?") and prompts participants to his own proposition ("consider: 2"). At this stage, since "Not application specific" is under an AND connective, using the predefined conflict resolution rules, the system infers that the whole model is in doubt.

The result of the insertion of an argument under an OR connective would have been different, as the parts of the model rooted in both operands of an OR relation may be considered independently as holding or in doubt. To defend the model, the proponent (or any other participant) has to defy the arguments of the Senior Project Manager by providing his/her opposition. Alternatively, the argumentation of the Senior Project Manager may result in the development team (including the proponent of the first model) to concentrate on his model, or on other participants' models that deal with the same issue.

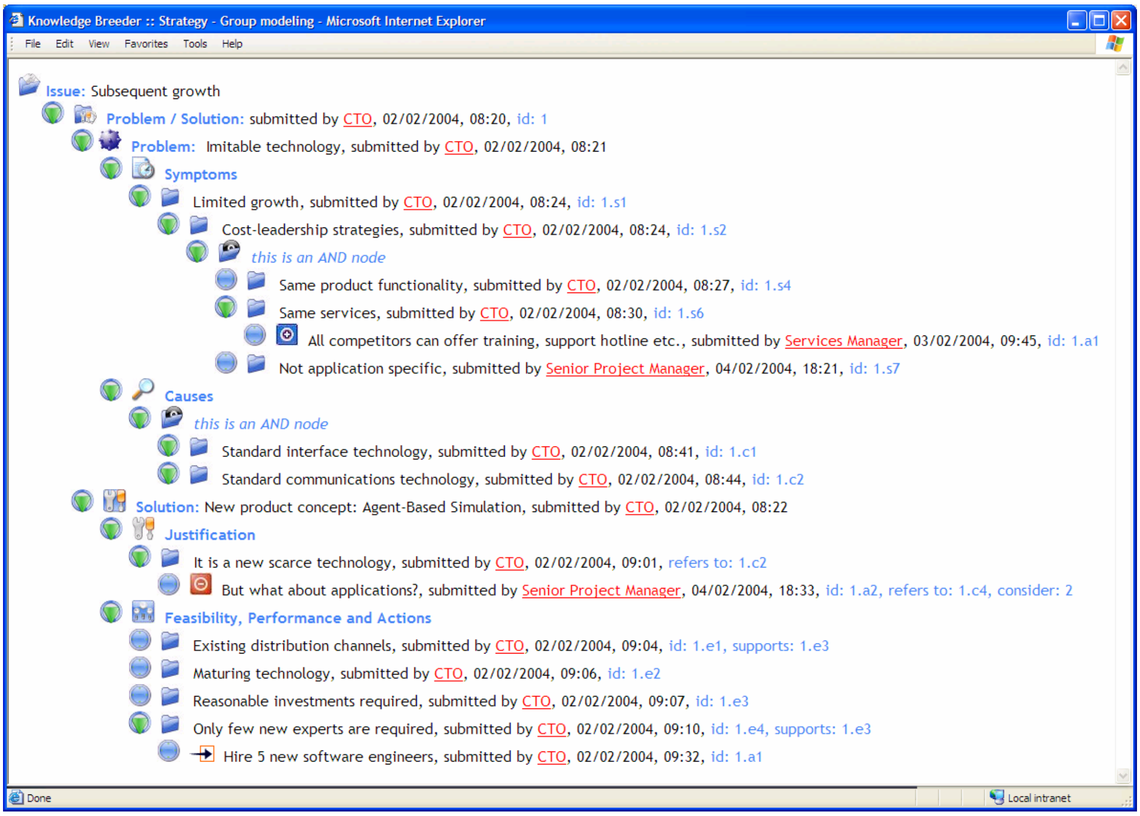

Fig.5. The same model with additional argumentation

Positions asserted as models are evaluated with respect to their defensibility (validity in relation to the shared understanding of the strategy formulating team). The defensibility of each model is a qualitative and indicative measure summarized at any instance in the discussion, in the form presented in Figure 6 (after six rounds of argumentation). There, participants can see which models, parts of models, or arguments are in doubt. By clicking on specific parts of the models, participants can see details of the argumentation, as well as more detailed statistics, e.g. the number of attacks on an argument, the number of successful defences, replies, etc. Of course, it is up to the participants' own judgment to make the final selection.

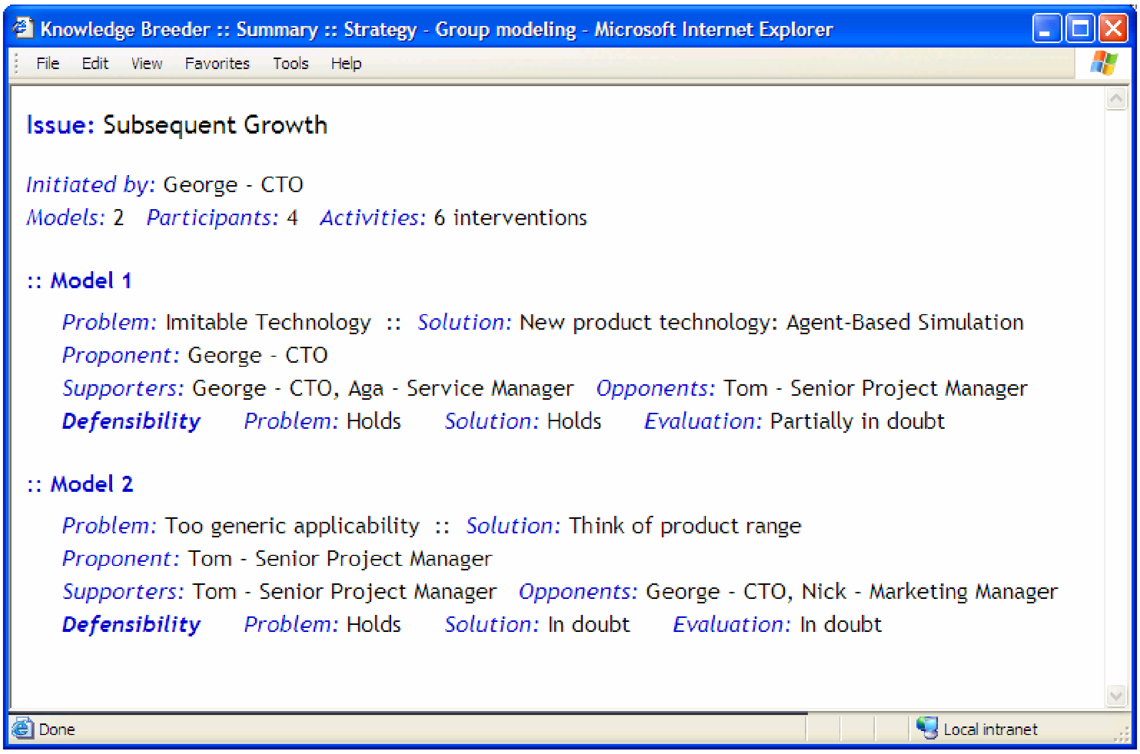

Fig. 6. Summary information for the evolving innovation concept

6 Conclusions

Innovation is a task that depends upon the individual and collective knowledge of employees. As a process, at each stage, it involves problem identification, problem solving, and prediction and anticipation. Social interaction is the most essential element of the process, and the role of information technology is to structure it in a manner that while, on the one hand, encourages divergence of perspectives, on the other, convergence to valuable outcomes is attained efficiently.

Towards this end, in this paper, we have presented how the collaborative problem-solving methodology G-MoBSA can be used to support the innovation process. In G-MoBSA, innovation is viewed as a breeding process where the innovative concept co-evolves with the knowledge pools of the individuals involved in the process. The core of the methodology consists of a problem-solution modelling formalism for providing consistent views of the issue and a formal argumentation schema for conducting the dialogue among development team members.

We have demonstrated the use of *Knowledge Breeder*, the IS framework that implements the methodology, through a sample instance of a particular phase of the innovation process in a software development company of add-ons for modelling and simulation environments.

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