Merits of different formats for learning and implementing System Dynamics.

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Abstract

This work has to do with the merits of each different format that the practice of System Dynamics had traditionally adopted. The merits are gauged by their degree of effectiveness and their participation in the different processes used in the creation of a model, as Forrester (1961, 394) has described. In System Dynamics we must ask what is essential and what is accessory, what must take priority for transmission, what is the minimum necessary format and what is of lesser importance? How necessary is it to maintain certain pre-determined standards in the model design? The merits of the different formats of the System Dynamics traineeship are not uniform, when it is considered how much each one of the styles or techniques described adds to each modeling process. When it comes to the 'light' type of exposure to System Dynamics, although this is not to deny the benefits of group work at learning seminars, there is no substitute for the experience implied by the realization of a complete modeling process, from the very beginning up to the end.

1. Introduction.

This paper is concentrated on the merits of the distinctive prototypes or formats that System Dynamics practice has historically made use of, in the light of their degree of participation in the processes implicit in the creation of a model as they were described by Forrester (1961, 394). From the beginning it was well known that the fate of a model is sealed by its potential for successful implementation of the operational policies that emerge from experimentation with it. It depends on the confidence of the client in the model. The pragmatic value criterion of the model has a certain influence on the flow of the discipline and, over time it has generated successive formats for the creation and implementation of models and the education of experts.

Considering the diffusion expected and desired for the discipline, what to teach and how to do it is not a minor problem. It is clear that to be a professional modeler it is necessary to have been working on models, from loop diagrams to the latest kind of simulators. However, what is the minimum necessary content for a successful exposure to System Dynamics? How necessary is it to respect some standard model design? Is System Dynamics a professional activity with its own identity or is it becoming weakened by the valuable and necessary interdisciplinary contacts? What are the kinds of problems we can expected to solve with this discipline? The generation of some kind of knowledge, whether this be technical, leading to direct action— or theoretical, for a model, is a process that has apparently been suffering mutations. The answers to questions such as what is essential and what is accessory, what must be given priority and what is less important appear, partially and successively, with the examination of System Dynamics' history, a history that has been dominated by different teaching criteria. To answer these questions would seem to be imperative to-day.

2. The degeneration of the original management educational format: the expert as an "outsider".

Forrester understood that the natural addressee of the model was not the expert who made it. He imagined, with exaggerated optimism, that the client himself could be involved in the construction of the model, and it would be used as a policy simulator: "The manager, like the engineer, can now have a laboratory in which he can learn quickly and at low cost the answer that would seldom be obtainable from trials on real organizations" (Forrester 1961, 43). For this to happen it was essential that the user understand the model and be able manipulate it, hence one of the Forrester's first preoccupations was to create a computer language approachable for the client. In the middle of the '50's in *MIT*, *Dynamo* was created with this purpose. It was invented as a language without the rigid concatenation of the typical rule of programming imposed by the professional language computer in force at this time, as was the case with *Fortran*. Dynamo allows the user to personally modify the model and the user can "establish controlling policies for his company and observe the results ... he will be concerned so much with day-to-day crises as with the establishment of policies and plans that minimize emergencies " (Forrester 1961,45).

Hoewever, instead of the original idea of having the manager as the modeler of his own company, the governing schema in System Dynamics practice was the solitary professional modeler, creator of the conceptual structure. From the '60's up to the '70's, the modeler was the almost exclusive protagonist in the practice of System Dynamics. The demanding curriculum for the formation of a modeler, carefully designed by Forrester (see Industrial Dynamics, Chapter 10), was for few people.

Forrester does not lose sight of the educational value of the manager's learning games, and he points out the similitudes that can exist between the games in vogue in the '60's and the models that were developed in *Industrial Dynamics* (1961). On this issue Forrester said that in the games the players have a tendency to familiarize with the reactions of the system, much more than with the internal structure, which is the real source of reaction. There are a great number of decisions taken inside of a social organism but the games only allow influence on a little part of them. "Like the real-life business system, the participant in the game views the remainder of the system as a black box that he attempts to poke and prod with his decisions to see how it responds" (Forrester 1961, 358). However, a strong non-linear causal relationship with a high connectivity dominates the social system and Forrester warned that the exploration method proposed by the games is somewhat frustrating. On the contrary the dynamic models, as exposed in System Dynamics, are crystalline: each linkage is represented by its corresponding mathematical equation. Thus with a universal mathematical language, both the particular equation's shape and the assumed values for the introduced parameters, are appropriately justified. Forrester does not likes the comparison between his models and the flight simulator "... designed to enhance and ingrain automatic responses in the trainee" (Forrester 1961, 358) for such games mean the trainee adopts his rôle without caring that he who plays the game understand the causes of the dynamics process that he is trying to dominate, or the consequences of decisions over long terms.

3. From the lonely modeler to the teams of experts.

The opening up of System Dynamics to subjects of the greatest public interest had a great impact and represented a new path for System Dynamics, a disturbing methodology that, with its claims, seemed almost to have no limits. Forrester moved from the level of the company to the urban scale (Forrester, 1969) and from then on to the global vision. At the beginning of the '70's, Forrester's concern was the viability in the long-term of the tendencies that showed the group of the economy's indicators on a global scale. The possible exhaustion of natural resources in the face of demands stemming from exponential growth inspired the polemical book *World Dynamics* (Forrester 1971), where somewhat Forrester naïvely assures us that "given a set of assumptions, the computer traces the resulting consequences without doubt or error" (Forrester 1971, 127). Both models *Urban Dynamics* (1969) and *World Dynamics* (1971) were the result of his own personal effort. However, it was time to work with a team, so Forrester stimulated his disciples to continue with his way of working, supposing that sustained effort on the same theme would not fail to impact. Once he had led the way, his disciples formed a solid work group and kept on doing the spadework for the attack on complex problems of regional planning (Hamilton et alii 1969), or they followed Forrester in *Dynamics of growth in a finite world* (Meadows et alii, 1974). *Urban Dynamics* (1969) was followed by Alfeld and Graham (1976) and Schroeder et alii (1975). However, these books turned out to be pure academic exercises. If we examine the reactions caused by the urban model of Forrester, it is evident that town-planners and politicians were unconvinced. Forrester imagined such reactions: the challenging style developed in the pages of *Urban Dynamics* pages summarize his own pessimism as to the practice of the recipes there explored (see chapter 7). In fact, someone who was outside of Forrester's circle noticed the situation. In this respect Roberts harks back to Brewer's opinion, referring to the urban models: "the initial underlying assumptions of the model's builder assured that the policy makers would have little use for their products" (Brewner, quoted by Roberts 1978a, 77).

The Forrester school strategy for the diffusion and acceptation of the experimental results of the model exposed in *World Dynamics*, had two supports; on the one hand he tried to improve the credibility of his model, and in this respect he attracted a group of experts from the different sciences to what he considered a new area of applied knowledge (Forrester 1971, 127). The reproduction and value of the original global model created by Forrester, in a new and extremely disaggregated version, was the result of a comprehensive effort by an interdisciplinary group of recognized experts in System Dynamics, still active in the 90's; the new results were introduced in an extremely technical book, *Dynamics of growth in a finite world* (Meadows et alii, 1974), with all the documentation on the developed models, destined for the academic community. The other support of the Forrester school came from focusing on a wider public. The results of the simulations were explained in a different report, easy reading directed to the common man (Meadows et alii 1972, Meadows et alii 1974). The authors' efforts to attain their objectives is manifest. Communicability of results was the first aim and with this criterion effectiveness in the implementation of the suggested policies was covered.

But on looking back one realizes that interest in the wider public was nevertheless characterized by work of an academic character already manifested when the criteriæ for validation of the models used were examined; and along with this criteriæ was the absence of practical directions for implementation. As has already been noted: "if the atmosphere surrounding the project initiation is one of an academic exercise, success will be difficult to achieve" (Roberts 1978b, 155). Also, the public nature of the models themes meant public interest tended to lose sight of the character of the user of the model. This is not a person but a bureaucracy, maybe without any executive responsibility. As a consequence, everything ends in a report received by an Agency, without it signifying, on the one hand, the obligation of the Agency to implement the recommendations in the report, while, on the other hand, the Agency may have no interest in putting into practice what is advised. It is all too remote from reality. When we are talking about a better comprehension of a phenomenon by use of a given mechanism, this seems to be the first example of a real interest in including the initiated in this kind of problem. It would be harder to involve non-experts but the whole thing could signify a milestone, in that the survival of the discipline, or its need for expansion, obliges us to move out of the strictly academy world.

4. The implementation of recommendations as a theme: the client becomes the center of the scene.

The main merit for this change must be attributed to Edward Roberts, one of the first of Forrester's disciples and soon one of the first Forrester colleagues in *MIT*; he created among experts in System Dynamics the concern as to the practical value of the results of their efforts. Roberts (1978a, 1978b), when he was back to corporate applications, created some strategies in order to avoid the results of the models being consigned to oblivion. In first place, when a project is selected, it is necessary to model with a real problem and it has to be important for someone else other than for the expert modeler, as has been repeatedly stated in the literature. The model must have believable objectives such as the examination of probable policies, rather than an Utopian approach. In the process of modeling itself, efforts must be intensified in order to convert the members of the modeled social organism into facilitators of future implementation. In this respect, it is convenient to improve the relationship, leaving out the lower ranks of the organization, by setting up mixed working groups where the actors interact with the modelers in the creation of the model. This in order to get as soon as possible the first version of the model. If the project takes one year to be finished, the first version has to be ready in three months, says Roberts (1978a ,80). When Roberts established criteriæ for the degree of detail that must be incorporated in the model, he was very explicit: "you first meet the client's need for details" (Roberts 1978a, 80). Roberts suggests the modeler use the same criterion as his client when it is necessary to judge a policy, using the discussion of the aggregation detail required for the model. "The modeled effectiveness measures should be consistent with real world measures that can be applied within the real organization" (Roberts 1978a, 81). But Roberts involved System Dynamics with an inconvenient antimony: scientific models against 'managerial' models. If Roberts were right, many of the excellent System Dynamics models would be outside of the admitted practice. There are many reasons for the equation's economy, besides the client's convenience, plus the advantages that offer a model as simple as possible when you have to understand why a given dynamic takes place.

5. The appearance of the client on the scene brings the mental models back into discussion.

The model in System Dynamics is understood as the result of a process whereby the expert is in agreement with the development of its own managerial context. It goes back to Forrester's concept of mental models to work out the mechanisms utilized to represent ideas and make them explicit. When Forrester affirms that the human mind has to be analyzed, he stresses two different aspects. On the one hand, Forrester states that mental models are vague and imprecise (Forrester 1971, 213). However, on the other hand, these mental models, apart from their imprecision, have such informative richness that they are an unavoidable information resource in Forrester's opinion (1987b, 143). It is evident that Forrester was right that mental information surpasses what is written and goes beyond the numerical.

But it is necessary to recognize, as has already been done, that mental models are not infallible. Literature (e.g. Morecroft and Sterman, 1994) abounds in the modeling of poorly structured problems because of a group that tried to solve the problems concerned, generally in their own company. Insofar, as a problem is being modeled, it means finding its most outstanding variables and it is interrelated by the relationship between cause and effect; the nature of the problem and its possible solutions are being apprehended. Sterman (1994), is probably, the writer who adopts the widest view of this topic. Besides what had already been said by Forrester (1971) there could exist pathologies: behavior interpretation, and the mental models that exist for this, can lead to very important mistakes. For example, in a group, some actors can completely misunderstand the behavior motivation of the other members of the group because they are not aware of a given objective. The group may be unaware of an organic discapacity of a member such as deafness, the real reason for the isolation of this member, attributed arbitrarily by the rest to different causes. This 'leap' from the motivation, of which interpretation is confused, to manifest behavior, which receives a quick qualification by the rest of the group, was described by Senge (1990) as the abstraction leap. Sterman (1994) describes other examples of judgement conditioning. He states that all decisions are based on mental models, schemes that condition the way of reasoning. In the same article Sterman analyzed an experience whereby a work group trying to reduce the ‘lead time’ in the supply chain was asked to make an outline of the problem specifying the ‘times’. The process has three stages: in the first one, the supplier is responsible for manufacture; the second one covers the management requirement and finally comes the client’s approval. The group were asked about the relative length of each of the steps. The second stage was considered the longest. It is an obvious answer because the group was functionally involved with the management requirement. Consequently we have a judgement dominated by the subjectivity of the group, since the management requirement had objectively a value of approximately one quarter of the other stages. The problem could not be solved without considering the point of view of the suppliers and clients. Sterman states, quoting Axelrod (1976), that cognitive map investigations show few of them incorporate fortuitous relations; many inter-related variables, because they are involved in numerous feedbacks confuse the task of looking for causes. People have a strong tendency to attribute the behavior of others to dispositional rather than situational factors. This is the main mistake: attributing behavior to the people concerned, instead of attributing it to the system structures. The focus of management is on the search for extraordinary people to do the job instead of designing the work to be done by ordinary people. With such a criterion, when attempting to design a new strategy or organization using a mental model, inferences would be made as to consequences of decision rules that have never been tried out and on which we have no information. People cannot mentally simulate even the easiest feedback system, the first order system. This restricted capacity for rational simulation limits the complexity of cognitive maps and our own ability to use them and anticipate the system dynamics.

6. Recent experience in mental models extraction processes.

Some experiences illustrate the methodologies at present being used, for the creation of mental models. Hodgson (1992) comments a method that he used to “extract” and set in order ideas, in an activity with a group of managers. The ‘basic unity’ in this process is a metallized hexagon that can be leaned against a blackboard and eventually its color can be changed. Ideas are being written on this hexagon (e.g. The market is not growing as we expected, the distribution loss is increasing, the innovation cycle of the product is shorter) that will be the basis of the subsequent analysis. Then the hexagons can be joined into clusters in accordance with how they sum up the meanings; at the same time the clusters are brought in according to the possible cause-effect relationship they imply. The color of the hexagons assigns an additional dimension: each color (e.g. opportunity = yellow, problems = black, innovations = green; there is a total of ten) contributes by giving the participants a more complete picture of the concepts expressed. Each ‘idon’ (idea + icon), used in combination with others would be a way of representing the deeper aspects of our mental models. Morecroft (1992), working with 10 Shell executives during the planning stage for an energy center, did not derive any standard lesson on the knowledge extraction process. However, there are procedures designed to involve the members of a team, to capture their knowledge, to make a map of the possible structures for inferring and generating the ownership feeling shared by the members. He concentrates on the analysis of the work process previous to the generation of flow diagrams and equations. The use of schematic diagrams like the one of the Porter’s Chain Value, would facilitate propositions and understanding of the details of the phenomenon under analysis, assuming that the proposed schema represents the theme sufficiently well. The model would be based on experience in the consultancy division of a company. Lane (1992) makes some generic affirmations about the formalization process of models for groups. He states that traditional consultancy does not consider that if a client does not assume the solutions as his own, the expert rôle can be refused: a manager will not put into practice a solution he does not understand. The client cannot accept that the expert is only expert in his own business and that this kind of modeling, as opposed to the classical type used in Operations Research, would be the right one. In his opinion, the new methodology should prevail in this matter, making the client a participant and owner of the possible solutions being generated, transforming the expert's rôle into solution facilitation on the understanding that the problems can be of a political nature. Vennix (1992) distinguishes between the modeler as an expert in model development, and the facilitator as a specialist in achieving development of the model by the other side. The potential of both is usable for different usable purposes during a team's work meeting. He also makes recommendations with regard to five critical factors in the process of knowledge extraction: the phases of the process, the kind of task and its purpose, the number of persons involved and the available time to finish the project. He quotes an example of what knowledge extraction can be in the construction of a model. The process begins with a project group (two persons) who design a preliminary draft of the model problem. Then he uses the "Policy Delphi Procedure" in order to have a number of experts (sixty, including doctors, researchers, financial experts, hospital directors) to formulate comments on the preliminary model. The first part of the Delphi consists of a questionnaire relative to the binary relations in the model, that is, the relations between two variables. The second cycle is built on results of the first and he continues the process by making the experts criticize more complex sub-models. In order to extract the knowledge of the expert group they use a "Workbook". The third cycle consists of a structured workshop where a member of the experts can briefly discuss parts of the conceptual model. Lane (1993) explains the steps followed to establish a preliminary model for recruitment and the career plans of the computer division in a European Shell branch. The work was carried out in groups. The author talks about three stages. For the first stage, five questions were prepared, focused in the same way as the "five hats of de Bono. These questions create a favorable climax for the discussion. At this stage the colored hexagons quoted by Hodgson (1992) were used and with the hexagons the main topics were selected. At the second stage, the process was addressed to the resolution of a specific problem (Medler's problem) related to the general problem that was designed to be solved. At this point it was useful for a system dynamics model, representative of the problem, to be sketched on a paper. At the last stage the model was taken to the computer, where the *Stella* software was used to generate different possible stages for the problem.

7. Flight simulators and learning laboratories.

The flight simulators supported by System Dynamic models were developed in *MIT* and widely used in a numerous educational community. The most well-known predecessor of System Dynamics flight simulators is possibly the 'beer game' that simulate a manufacturer's situation, a wholesaler, a retailer and clients faced with a demand variation. It is typical to see the reactions of the different players if the game is set up: faced with a demand that does not suffer fluctuations over time the players are unaware of the delays and requirements involved that may generate sudden variations in the different demands. In general, they react imaging that the situation has been provoked by external factors. Senge and Sterman (1992) suggested as an aim the development of a learning environment to motivate; to give lessons both experimental and cognitive; to allow to compress time and space in order to experiment the long term consequences of the participants' actions. In a balanced way, they tried to define the teaching virtues of flight simulators. In opposition to the general philosophy of using flight simulators for the case method, Graham et alii manifest their reserves with regard to this topic: "However the case method has limitations. Chief among these is the impossibility of testing hypotheses the participants offer as to the effects of alternative actions." (Graham et alii 1992, 221). Stressing the importance of taking dynamic decisions Graham et alii mention research that shows "that environments characterized by many feedback process, collateral effects, time delays, and non-lineal processes, are particularly troublesome" (Graham et alii 1992, 221). Several experiments reported by the authors show students and managers suffering from misperceptions of feedback, which would result in "extremely poor performance and slow or no learning". These authors also say that the simulation methodologies of the system dynamics kind help to overcome the lack of feedback perception, a real plague for managers in the real world. System dynamics offers a framework for the conceptualization of complex business and other situations, tools to identify the physical structure, the organizational structures and the decision makers in the system, plus simulation methods to help infer correctly the inter-functional relations of this structure. Graham et alii understand a behavior theory based on the feedback structure of the business environment surrounding, that endogenously generates the problem behavior described in the case. The System Dynamics models would be, according to this line of thought, particularly suited to understanding the coordination between strategy and operational policies, how to distinguish objectives from strategies designed to attain objectives, how to design a whole set of policies and programs that support strategic objectives. In this way, models of cases would provide an important link between strategy formulation and implementation at the level of operation management.

Learning laboratories develop as an extension of the experiences with simulators by structuring different sessions that include the use of simulators, discussions and workshops (Baken et alii 1992; Kim, 1989), a process is developed that helps to achieve one own experiences and knowledge. Baken et alii (1989) introduced what they call a generic design of a learning laboratory. They refer to a case in the insurance industry, a laboratory was built for the trainees dealing with claims. The company concerned tried to improve its claim's attention service and found the very best balance in the quality of the service. The author proposed four stages for the laboratory concerned. In the first stage, the environment is defined in order to establish the key variables to be considered both internal and external, and the specific scope of the problem. In the second stage the key factors that determine quality are conceptualized, behavior patterns are sketched, structural explanations are provided and the intervention points are identified. In the third stage the hidden hypotheses are discovered. Finally in the fourth stage, knowledge is tested and reflected by using the simulator: each team is asked to do the following, step by step: to plan a strategy and put it in writing, to predict the consequences of the strategy execution, to sketch the behavior over time of some key variables, to trace the game's results and to explain them to the rest of the group. The authors give as text cases an engineering division, a claim's office, the loan division for a bank, and a training department specialized in selling places to apply the methodology. Another example also quoted by Bakken et alii (1989) is a learning laboratory related to the case of *People's Express Airlines*, an American airline very popular at the beginning of the '80's. The authors aim to measure knowledge transparencies of three types— to understand the points of the case, to acquire a comprehension of the underlying feedback structure and to transfer the knowledge to other contexts. Graham et alii (1992) introduce another case that is not accompanied by what is strictly a simulator. Intercom, a supplier of telephone systems, must change the base of its products from electro-mechanical systems to electronic ones, and the case is organized around three flow-stock diagrams. There are other simulators developed by Sterman at *MIT*, that are supported by system dynamics models. B&B Enterprises simulates the situation of a fictitious company; based on real cases: the situation is that of a product introduced into the market and its subsequent evolution over its working life. *Commercial Real State* is another simulator that deals with the situation of a company from the real estate sector. *International Oil Tanker* is the case of tanker oil carriers (Bakken 1993).

Finally, something significant had happened: Harvard Business School incorporated into its training methodology the interactive simulators that use System Dynamics models for operational support. In the well-known *Balancing the Corporate Scorecard* of Kaplan, provision is made for a software company that allows the users to select their own control parameters; two programs at least were added (see *Harvard Business School* web site), in a development plan that seems to be very ambitious, considering that Harvard University has associated with one of the main software maker on the market for System Dynamics, *High Performance System, Inc*. The enterprise was also supported by a very important group of companies, joined together in a council of interactive media users (Interactive Media User's Council) with companies of great importance and prestige such as AT&T, Federal Express, Hewlett Packard or IBM.

8. A crossing of the various formats for System Dynamics practice with modeling process stages.

Forrester established in *Industrial Dynamics* (1961, 354) a series of intellectual activities that have to be carried out in every design process of a System Dynamics' model. The Forrester schema has a dual importance. On the one hand, it allows for a distinguishing process, a very important task in the pedagogical area. On the other hand, the effectiveness of the different methodologies in each process mentioned by Forrester can be analyzed. The following chart compares the stages, as they appear described in the second column, crossing them with all the revised methodologies, as shown under headings in the first row of the chart. These learning/implementation methodologies, shown in headings or formats are— reading the chart from left to right— in the first place, flight simulator use; in the second place, training in laboratories with a pre-established format; in the third place, participation in the mental model's definition; in the fourth place, interactive participation in the case implemented and recorded on a digital compact disk (CD-ROM); and in the fifth place, participation at every stage in the construction of the model. From the crossing of both criteria— the sequence proposed by

Forrester for the process of construction of a system dynamics model and the different implementation— there develops a bi-dimensional table, where an X letter indicates, according to the authors' judgement the suitability of the pedagogical practice in the corresponding process.

On the other hand, System Dynamics is introduced at levels that correspond to the different learning capacities. The first and most important is the professional one for those following academic programs. The second would be for the initiated who know the rudiments of the discipline without having developed models on their own. The third level is for model users that collaborated in the definition of common mental models in groups set up ad-hoc for the resolution of a problem.

From a study of the chart it is obvious that the experience with simulators is the poorest of the alternatives. It is limited to interacting with the model under pre-selected conditions. In this way it is similar to the experience of the cases introduced into the CD-ROM format with the advantage in the latter case, that the experimenter can revise the model's premises, although he cannot modify them. Obviously the participation in groups for the mental model's extraction is very rich in its identification with the first stage of the modeling process although it languishes towards the last stages, leaving insights only. The participation in learning laboratories is as is described above (Bakken et alii 1992) except that because the model itself appears as given, it allows participation in almost every stage of the modeling process. This, along with the presence of a strong focus on concentration, means that the format is one of the most powerful from the point of view of its pedagogical effectiveness. We leave to the last the consideration of the original format's quality, as defined by Forrester: the modeler who participates in every stages of the modeling process. This format, typically adopted by the programs for Master's degrees and doctorates defines, whenever possible, the characteristics required by a professional model of System Dynamics. In terms of the efficacy, the participation in laboratories and discussion of the pre-modeled cases on a CD-ROM, allows for an intermediate training phase that comes after the beginning but does not entitle the student to a full professional qualification.

Considering the participation of each type of practice in the modeling process, there is an obvious potential for thorough preparation, as is required when someone is capable of producing a complete model, respecting full participation in the modeling process. The question is what is essential and what is accessory in all these methodologies? From a systematic point of view, the answer seems to be obvious. Eliminating any of its parts means the whole changes, and, although it keeps on working, it is not the same. And the same questions must be asked as to the kind of training in System Dynamics that is to be given: what should be the modeler profile and how can it be achieved?

Summary of the considered facets by the different learning techniques.

	Learning techniques τ **Modelling steps o**	Flight Simulator	Laboratory	Participation in the extraction of the mental model	Cases with models on CD-ROM	Modeling experience
1	Define the system's objectives under study		X	X		X
2	Observe symptoms		X	X	X	X
3	Detect the real problem		X	X	X	X
4	Visualize the system into questions		X	X	X	X
5	Estimate the limits that underlie the problem's causes		X	X		X
6	Select the factors to work on		X	X		X
7	Construct a formal model of the precedent					X
8	Use the model to simulate the interactions of the system under selected conditions	X	X		X	X
9	Interpret the meaning of the simulation result	X			X	X
10	Invent improvements in the system					X
11	Repeat every preceding stage to come closer to the real problems and to the best management policies					X

Indubitably, it is a question of different training processes but there exist different objectives too. In the case of mental model explicitors, it is useful to have their involvement, marking the boundary between the objective of information harvesting and the verbal expression of the phenomena that are to be reproduced and analyzed. These phenomena would appear to have originated in management history, when at a given moment (possibly in a Japanese quality circle after the second World War) the tendency to involve personnel not necessarily top-level in the resolution of operational and strategic company problems was manifested. But will this involvement lead to a better quality of model, in the sense of its greater rigor and adaptation to reality? The answer seems to be obvious: the more the preparation, the better the quality of the model. An example foreign to System Dynamics can be useful. There was an unquestionable success in Japanese quality circles as a result of the experiments carried out in other countries. But is not clear that it is exclusively because of the group involvement. It could also be supposed, from another perspective, that the superior technical skill of Japanese workers could be the most important reason for the comparative advantages obtained by Japan between 1970 and 1990. The reality of senior Japanese education stands out when the country is visited.

An example, by way of analogy, is useful to illustrate the difference between the superficiality of knowledge and the true understanding of a phenomenon. In his book *The fifth discipline*, Peter Senge introduces the generical conclusions of the Forrester model in the model for "Market Growth and capacity expansion". The work is introduced with general comments, such as "in complex systems, obvious solutions often fail to produce intended results-in fact, they often exacerbate the very problems they are intended to resolve", continues with a problem description that includes causal loops diagrams, and some graphs that show tendencies of the model in general. Because it is about a relatively simple model, intuitive comprehension appears as unaffected. Introducing a non-initiated reader to this text would lead him to suppose that it is about an easy apprehension phenomenon. However, when the same problem is introduced but with the format of a case, with no other formal auxiliary explanation (e.g. causal diagrams), the difficulty seems to be of major importance. Only by beginning with the model's construction would it appear that the students acquire the relevant knowledge in a solid enough way to be able to state that the command of the subject is complete.

9. Conclusion.

The System Dynamics model was imagined, from its beginning in the '60's, as a guide to action. Forrester utopically imagined each manager modeling his own system, to answer his own difficulties. He wanted to differentiate his focus from the simulator games that aim at the automatic generation of answers. But, in fact, the academic programs that the System Dynamics students must approve grew and led to the formation of an expert who saw the organization from outside, as an outsider, who prescribed given policies in the solitude of his laboratory. The first model's generation, as a result of personal efforts in corporate application, in the majority of cases was followed by a second wave concentrated on problems of public interest, in the middle of the '70's, such as urban, regional and global models. The strategy used to improve the impact of such models was supported, on the one hand, by the expert's incorporation into the modeler team in the modeled area, and on the other hand, by the generation of reports destined for the public at large. However, the absence of a specific recipient, with executive responsibilities, conspired against an effective implementation of such urban, regional and global study recommendations. The client for the model was still absent in the modeling process. Simultaneously, as in the '70's, Edward Roberts defines a clear strategy for the acceptance of a model based on a correct perception of the problem to solve; the intensive involvement of the organization, etc. This was at the expense of a progressive breakdown of academic System Dynamics practice. The criteriæ of the marketing consultant developed and conflicted with the academic approach.

In the '80's the System Dynamic experts started using some psycho-social tools with a view to involving the potential client from the very beginning of the model's generation, even at the risk of making the model lose its scientific rigor. What began as exploratory, was established as the main theme in the '90's. Such group psychology techniques became indispensable for mental model generation with the aim of generating the identification of the structure that underlies the consciousness of the member of the organization subject to modeling. The materialization of such knowledge extraction techniques is very varied, from the use of magnetized hexagons on a blackboard to fix the ideas emerging in the group discussion, to a long-winded characterizations of the facilitator rôle, that allows cognitive maps to develop. Once the computer was popularized, it was logical that the *Beer Game* turn into sophisticated interactive games, which have as support a dynamic model. With the learning laboratories and flight simulators, the client becomes a protagonist, but the model is hidden, its usefulness a polemical topic for the experts community. Learning laboratories are based on with training through intensive flight simulator sessions. The cases with models on CD-ROM are the last link of the chain, may be the most sophisticated one joining abilities that were supposed to be contradictory, or at least, that seemed not to be able to develop in a parallel way: The analytical capacity and the verbal discursive one.

The explicitation of the internal structure of a model is indispensable for acquisition of the minimum data on the analytical problem through experience with the so-called 'business games'. However, at the same time it seems to be difficult to acquire the professional modeler's skill simply by starting from experience with such games. The importance of group work cannot be denied. But it must be emphasized that it is not a substitute for the complete experience implied by the realization of a model. Trying to distinguish the essential from the accessory, it can be said that there is a kind of 'objectives degradation' in the different model training proposed. It is very difficult to find practical teaching objectives (except for the mere transit to an upper stage) on the learning scales already defined. However, the intermediate scale for the initiated can lead to a better understanding of the phenomenon analyzed than if that they had never had this knowledge, but it will always be a partial understanding since they do not go deeply into the subject by developing a model and participating in all aspects. From the analysis of the different learning/implementation patterns that has have been developed, it has to be said that each has had its use. The lecturing knowledge that has been generated with this objective— Sterman comments are particularly relevant here— is less commonly praised. An incipient science has developed that studies a traineeship for taking decisions in dynamic surrounding, in which the influence of System Dynamics as a discipline with own importance has been decisive.

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