SYSTEMS THINKING LEARNING FOR MANAGEMENT EDUCATION. WHAT ARE OUR IDEAS AND HOW ARE WE GOING ABOUT IT IN SEVILLA?

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ABSTRACT

A great number of System Dynamicists coincide in our belief that the methods and tools presently used in virtually all management education centres insufficient to cope with an ever more complex reality. For some years now there has been a significant movement within our field which aims to provide alternative ways and tools which will serve to fill the existing gap.
Working along these lines we created a work group and started, within the EC Comett framework in 1990, a project termed "Learning laboratories in computer-aided Systemic Business Management", sponsored by numerous European firms and institutions. The aims of the project are multiple and interrelated: production of learning tools based on System Dynamics, facilitating reflection on causes, design of learning laboratories in business management following a systemic approach, trying out the tools created and checking learning processes for different circumstances, development of training courses, promoting training of trainers.
In a period when the time available to managers is scarce, and increasing complexity makes the need for learning more critical, open learning must play an important role. To this end we must consider creating tools which will allow the user, even in the absence of the teacher, to have as much access as possible to reflection on causes, to decision-making based on causes and not on symptoms, in short to systemic thought. The "transparent box" games mentioned above, together with proper documentation and a special attention to the training of trainers, may represent, in our view, an advance on present tools.

1. INTRODUCTION

The methods and tools used at present in virtually all business-management training centres are insufficient to cope with the complexity characterizing business systems, which makes decision-making in them particularly difficult (1).

First of all, **the traditional system of teaching** tends to encourage the analytical approach, a classic element in our educational system from infancy up. On top of this, there tends to be an excessive theoretical load, and little participation on the part of the student. The former generally leads to specialization, which is excessive at times, bringing with it the tendency to optimize partial goals to the detriment of overall objectives. The latter gives rise to passive learning, with little motivation.

Secondly, **the case method** undoubtedly possesses positive features, such as favouring the exchange of ideas, motivation, participation, observation, reflection and the discovery of new ideas. However, in its traditional form, this method is insufficient to deal with complexity and change, as has been stressed in numerous publications (2).

Finally, with regard to the case method, **traditional simulation games** have the advantage of direct interaction between player and computer, as well as offering the possibility of observing the result of the decisions adopted. However, as they are of the so-called black box type, the internal structure which generates the results of the simulation is not very well-known, or is deliberately concealed. As a result (3):

1) the learning assumed is attained through a system of trial and error in which the player does not really know the origin of the results obtained, although he bases his decisions

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on the latter (the symptoms).
2) the basic structure of the simulation model might be erroneous, with no possibility ofdetecting this fact. This may lead to faulty "learning" with little chance of correction.
3) adaptation with a view to suiting the learning to changing conditions becomes practically impossible.

Management Simulators based on System Dynamics models (both generic and presenting real cases) and Learning Laboratories undoubtedly represent a significant advance in the field of Business Management Training. We agree with P. Senge and J. Sterman (1992, p.129) when they point out, referring to these laboratories, that they will help overcome the persistent difficulties facing management in complex organizations, difficulties which can increase dramatically in a rapidly-changing global environment.

In view of the above, and with the aim of contributing to the improvement of business-training methods and tools, the work of the G.I.D.E.A.O. group (4), which I direct in Seville, has, since the end of 1990, been centered on a project we have named "Learning Laboratories in Computer-Aided Systemic Business Management" (EC COMETT Project 4632cb).

The present paper has a twofold aim. First of all, we shall deal with some of the questions raised but still not resolved in this new field of research, namely:

* are transparent box management simulators more suitable?
* how far should we go in exploiting the new information technologies?
* in what way, and how intensely, should the training of educators be tackled?

Secondly, we shall give an account of what we are doing in connection with these and other questions.

2. TRANSPARENT BOX MANAGEMENT SIMULATORS VERSUS BLACK BOX MANAGEMENT SIMULATORS.

I think we all share the belief that a knowledge of the causal structure will facilitate an understanding of the phenomena that appear in social systems and, more generally, in complex systems. My conviction about the importance of the use of the causal structure as a vehicle for reflection aimed at a closer understanding of such systems and for easier decision-making within them is as firm as it is long-standing. However, I recall that the first time I communicated this belief was to Alan K. Graham during the period I spent with the System Dynamics Group of the Sloan Management School in 1988. I raised the subject again at the Conference held at Pine Minor College (Machuca, J.A. and Román C., 1990). Later on, in Bangkok (Machuca, J.A., 1991) I insisted on the importance of making the games that were being developed transparent ones, in order to facilitate reflection on causes and avoid the black box approach. These reflections were subsequently published in the System Dynamics Review (1992).

In 1990 we moved on from the idea to action, in starting the project mentioned in the previous section, which has as one of its objectives the creation of training material consistent with the above-mentioned ideas. Part of this material consists in the development of transparent box management simulators (TBMSs), working from new models or the adaptation of already-existing ones (5).

Although we shall be dealing with this matter in greater detail later on, it should be mentioned here that one of the features of these TBMS is that the causal structure of the model on which they are based is accessible to the user at all times, as are its principal equations. In addition, when they are used in training courses, the participants must recreate and understand this

causal structure before the simulation stage. This concern is now shared by numerous colleagues, as can be observed in various works and publications. Among others, we can cite the following:

*Eberlein Bob, who in VENSIM (Ventana Systems, Inc., 1.988-1.991) introduces the possibility of causal searching and visualization of the corresponding behaviour).
*Isaacs W.N. and Senge P.M. (1992, p.195), who believe that designers should not be protective with the models on which Computer Based Learning Environments (CBLEs) are based, and that these should be redesigned to incorporate reflection upon spoused theory, aiming at the development of conceptualization skills and also reflection on actions brought about in simulations and their causes.
*Kemeny, J.M. and Kreutzer B. (1992, p.305), who refer to "White Box" in the design of the Management Team Flight Simulator (although I would insist on the term "transparent box", since white is a colour that is just as opaque as black).
*Morecroft J. (1992, p.465) thinks that there is a danger that the simulation game will be treated like a black box whose structure is difficult to understand, and believes that it is necessary for participants to be briefed in Systems Thinking and in the causal structure of the model.
*Peterson (1992, p.117) points out that even an expert modeler may find it difficult to communicate fresh insights concerning a model if it appears to the audience as a black box.
*Sy-Feng Wang and Showing Young (1992, p.765) argue that if the aim of a management flight simulator is to increase understanding of the structure or the capacity for systems thinking, the structure must be reflected in the simulator and the learning program must stress the importance of understanding this structure.

There are several reasons for our defending the use of transparent box games. Knowledge of the causal structure has always been essential for the development of System Dynamics models and access to the structure during the use of MFSs aids the development of Systems Thinking among participants. This facilitates causal reflection and favours systemic learning of social and business problems, helping to prevent the video-game syndrome which often arises in black box games. We are convinced that this is a good way to enrich managers' mental models. With a view to testing our hypotheses we are experimenting with various groups of 3 or 4 people playing with the same simulator, but under different conditions: some with the black box type and others the transparent box. To measure the performance achieved in the learning process, we are using:

a) the results obtained by the different groups in the simulations.
b) the comments and discussions of the different groups during and after the game.
c) the learning transfer from one game to another, different one.

Our experience so far has confirmed our hypotheses. The general opinion of the users of games designed in these terms is that the search for the causes of the different behaviour observed and the subsequent decision-making based on them clearly improve the traditional learning process to which they are accustomed. Their opinion is that a clear view of the relationships between the different variables of the system permits them to deepen their knowledge and to have a more realistic understanding of the problems raised. They also believe that it is more fruitful and productive to play in a team than individually due to the synergy generated by the discussion. Likewise, those who play with transparent box simulators believe that it is more and more convenient to operate in the process of decision-making based on the search for the causes of the simulation results.

Moreover, our experience in using TBMSs in the context of learning laboratories and training courses confirms that better results are obtained in the learning process if the participants are trained in the process of conceptualization and are required to produce the causal structure

representing specific cases. In the initial phase this is done individually, so that each participant reflects his own mental model; in a later phase there is discussion of the different diagrams obtained and a causal structure is reached on the basis of consensus, representing the specific case. This process is unanimously considered to be extremely enriching and enlightening; for many, this alone justifies participation in the training course. They also consider that its application to management board meetings would be of great value since, with the causal structure being made explicit, there could a common basis for discussion of the different questions raised (6). An additional advantage to this process is that it makes it patently clear that **a number of individuals tackling the same problem conceive mental models which do not coincide in their entirety**, and that it is necessary to reach a structure through consensus before attempting to discuss and solve a problem as a team.

The simplest way to introduce the structure of the systems studied as part of the accessible information in management simulators is through the corresponding causal loop diagrams. If this is done, and with a view to improving the information offered by these diagrams, it is important to bear in mind the observations of G. Richardson (1986) and to distinguish in some way the rate-to-level links within them.

Another feature we have introduced into the simulators is the possibility of the player being able **to alter the structure of the system under simulation**, by activating or deactivating parts of it. Thus, for example, it is possible to start off with one basic structure and gradually increase the complexity of the game as and when required, there being in principle no limit to the number of substructures that can be activated. In the same way, it is possible to activate one set of variables and deactivate others, which enables participants to change, for example, both representative substructures of material factors (e.g:technology used.) and also aspects of management (e.g:production policy.). Possibilities of this type, therefore, make it possible to experiment with new situations, involving both internal changes and changes in the environment. This substantially increases the number of learning experiences and, in our view, considerably improves managerial capacity for adaptation and the potential of the simulators.

We said above that in our TBMSs, not only the causal structure of the model is accessible, but also its principal equations. Now, one fact we have been able to observe is that causal structures are used much more than equations as a source of information for decision-making. Discussion of this point with users of the games reveals possible reasons, although they have not yet been comprehensively examined. They are the following:

* Causal structures are more easily understandable and give a rapid picture of the problem.
* The cases under study are not excessively complex and do not make it necessary to search in greater depth for the causes underlying the behaviour observed.
* Causal structures fit more easily into the decision-making scheme of many managers, accustomed to qualitative information and to the application of their own mental models.
* There is a certain rejection of mathematical equations on the part of many managers. It is interesting to observe that the higher the level of the manager concerned, the less this source of information was used in the course of the games.

Logically, we do not consider the various conclusions commented on in the course of this section to be final and conclusive. The number of users observed in our learning laboratories is not, as yet, great enough to enable us to generalize on the results we have seen and the conclusions that have been drawn. Nevertheless, we believe that these may help to shed more light on a number of important questions:

* how should we design management flight simulators?

* how does knowledge of the structure influence the learning process?
* what knowledge should be given to individual users of the MFSs?
* what knowledge should the participants in the CBLEs be supplied with?
* how should the briefing be organized?
* how should the debriefing be carried out?

To come up with the answers to these and other questions connected with MFSs and CBLEs further progress must be made, increasing the number of experiments and the size of the samples, using different games, altering the degree of complexity of the cases, etc.

3. AN APPARENTLY CONTROVERSIAL QUESTION: HOW FAR TO EXPLOIT THE NEW INFORMATION TECHNOLOGIES IN MFSs DESIGN.

The new information technologies (IT) offer us numerous valuable tools which can be used in the design of business simulators, from the now familiar Hypercard, Stella Stack and Supercard to the integration of multi-media technologies (video, sound, etc.). The question raised is: How far should we go in using these tools? As to the answer, there seems to be no consensus within our scientific community.

On the one hand, there is an increasing number of studies presenting approaches which imply an increase in the use of IT (7) or which regard them as a promising road (Peterson, 1992, p.202). On the other hand, we can recall other voices (Meadows, 1989, p.639) declaring that, in the development of games, it is dangerous to be too concerned with technology and that "shortcomings or special features of the technology shape the game experience so that it has little relevance to the social or economic situation within which the insights must eventually be applied". It is also common to hear talk of the danger of the video-game syndrome.

These fears are well-founded and warn against a widely-recognized and serious danger. However, we believe that, being familiar, this danger can be combatted and, with this in mind, exploring the possibilities offered by IT need not be prejudicial but, on the contrary, can and should be beneficial. Among the benefits that can be obtained are:

* making the games more attractive, and accordingly more widely used.
* increasing the quality and quantity of information reaching the user, thus providing easier access to a knowledge of the problems, and an improvement in decision-making.
* smoothing the way towards self-sufficiency in the player-game relationship.
* etc.

These features are essential to promote the expansion of systems thinking to a considerable number of people in the absence of teachers/trainers who are experts in this approach. Besides, for some years there has been (in the EC at least) a growing awareness that, at present, training to increase business competitiveness is of critical importance. Moreover, it is an incontrovertible fact that managers, being overloaded with work, have little time at their disposal, which makes it more difficult for them to have access to learning, particularly if it involves moving outside the place of business. In view of the above, it is not strange that more and more attention is being given to those approaches which facilitate teaching without a teacher, or with little contact with one (open learning, distance-learning) or that the use of the new information technologies is being promoted to achieve the objectives proposed. All of this constitutes a top-priority objective within the EC today.

Our scientific community should not distance itself from this reality, and we must create learning tools which, in this context, will permit the training of managers in decision-making with Systems

Thinking. In order that this may be achieved with the greatest guarantee of success, we should design our games using all the facilities we are offered by the new information technologies, though trying not to fall into the dangers pointed out by Meadows a few years ago (1989, p.639 ff.). Thus, on the one hand, we have to succeed in making business simulators attractive and motivating in themselves, while preventing the player from being absorbed by their form and technology, or else by the difficulties presented by the mechanics of the game, and therefore not achieving the objectives proposed in it, namely the acquisition or reinforcing of Systems Thinking (and along with this an improvement in the individual's mental model) as well as assimilating an experience analogous to that of the reality simulated.

In addition, it should be recalled that we ought to devote particular attention to the testing of the model which serves as a basis for the game, as well as making a great effort to offer quality documentation, which should include:

* a good briefing, presenting the case and allowing the user to attempt to produce its causal structure.
* one or more guided simulations to familiarize players with the software used and the search for the causes of the behaviour observed.
* a good debriefing of such simulations, going further than simple guidelines.

Given that, in the context presented here, an extensive distribution of MFSs is possible, as is their use by individuals (in the absence of the teacher, or having little contact with him), the conditions mentioned would help ensure a more suitable use of the MFSs. There is no doubt that when a MFS is used in the context of a Learning Environment in which the facilitator is an expert in System Dynamics, there will be less need for the computer to offer comprehensive information or for sophisticated information technologies to be used. However, this case cannot be very frequent, if we consider that such experts are few and far between in the various countries concerned. In fact, our scientific community has been concerned for a long time about the insufficient dissemination of System Dynamics, the application of which is truly minimal in universities and practically non-existent in secondary education. If we wish to alter this situation, and also realistically face the context described above in such a way as to facilitate the dissemination of System Dynamics or, as an important preliminary step, that of Systems Thinking, we will have to try to take, advantage of the advances offered to us by the new information technologies. While taking into account. The observations mentioned above

We, for our part, are working along these lines in an attempt to make the most of MFSs as far as the acquisition of Systems Thinking is concerned. We are consequently working on our own software for the development of games combining simulation in Stella with Stella Stack and Supercard, so that we will be able to satisfy the needs which in our view must be satisfied by business simulations, as outlined above.

One of the features we are taking into account is that of **facilitating the causal search** on the part of the user within the structure to which he has access by virtue of operating with a TBMS, which is particularly useful when the structure is marked by a certain complexity. In view of the behaviour of a variable, V, the possible causes of which are being examined, the basic procedure (which is already functioning at prototype level on a simple model) is the following:

a) Activate the causal loop diagram and locate the variable, V, in question.
b) Click on V, thus causing all the variables directly influencing V to be highlighted.
c) Click on these variables, which will lead to a graphic representation of their behaviour.
d) Analyse these graphics and decide which of them could be the main cause(s) of the evolution of V. This will involve clicking on the variable(s) in question, thus recommencing a process analogous to that expressed in b).

e) Continue the analysis until a satisfactory explanation is judged to have been found.
f) Make new decisions and continue with the simulation.

Another aspect we are tackling is the **introduction of sound, animation and video** so that the information can be obtained in a more attractive and motivating manner.

We are also working on TBMSs simulators (in all cases of the transparent box type) which will function within a network, allowing more realistic experimentation for team work. Thus, for example, the model for a generic firm will include decisions in the different Departments of which it is composed (Production, Finance, Marketing, Personnel, etc.). Each group of decisions is the responsibility of one member of the team, and the decisions are made on a particular computer, from which there is no acces to other decisions within the company. In addition, there is another computer, operated by the facilitator of the game, into which are fed any changes in those factors which do not lie on the decision-making level of the management of the hypothetical firm. The various computers are interconnected in such a way that the decisions and changes introduced into any one of them will automatically affect all the others, as happens in real life. We hope that, by the date of the Conference, a prototype of this MFS will already be working on a simple model. The idea is to work from a case study in a manner analogous to that outlined in section 2 for individual MFSs. Once they have grasped the case and the causal structure representing it, the members of the team hold a preliminary meeting to discuss the initial situation and the strategies and policies to be followed. Those responsible for each department then move on to their respective computers and make decisions for a given period of time. From this point on, the members of the team will have regular meetings to analyse and discuss the situation together (as happens with board meetings in companies), followed by periods of individual decision-making on the various computers to put into effect within the different Departments the policies decided at each board meeting. We believe that this type of MFS will make it possible to study the organizational learning process in greater depth.

Although we are of the opinion that the use of information technologies is necessary, we believe it is not sufficient; in order to achieve better results in relation to our objectives, it is essential to insist upon another crucial aspect which we shall examine in the following section: the training of Systems Thinking trainers.

4. A CRUCIAL TOPIC: THE TRAINING OF SYSTEMS THINKING TRAINERS.

Even though many might hold that having played with a game several times is sufficient preparation for using it for teaching purposes, the reality is quite different: it is in fact much more difficult to work with it as a teacher/facilitator. Although good design and good documentation reduce the danger of incorrect or poor use of the MFSs and may make a great contribution towards the expansion of Systems Thinking, this is not enough; investment must be made in another fundamental area: **the training of trainers**. This aspect is receiving special attention at institutional level within the EC and is particularly important in our discipline where, as we have already stated, the number of experts per country is very low. In our view, at least initially, to be a Systems Thinking trainer and be able to manage to exploit properly the material developed by others, it should be sufficient to be in possession of the first three levels of System Dynamics Expertise mentioned by Meadows (1989, p.636):

* Capacity to understand the system.
* Capacity to carry out a specific decision.
* Capacity to put into effect a recommended policy.

The time and effort required to enable someone to reach this level are much less than would be

needed to attain the seventh and final level. As a result, both in business and in the universities, people are more willing to devote the necessary time to achieving it. In our project we have been working on two fronts to add incentive to this willingness:

a) By generating the necessary interest so that in a specific group (firm or university) the desire will arise for one or more of its members to become trainers. We aim to achieve this:

* by presenting Systems Thinking and TBMSs as a new and promising approach, essential for management training and decision-making. We have done this in Congresses of Management Teachers and Technical Sessions within Educational Material Fairs in the area of Business Management.
* by means of courses in Systems Thinking for teachers and business managers. In these courses we pay particular attention to two basic aspects:

- After examining the case under study, participants try to produce the causal structure representing it, as mentioned in section 2 (8).
- When the case is one to be simulated, the participants are asked beforehand to draw the behaviour expected after their decisions. This serves to show that, in general, such forecasting is not obvious when the systems are complex. It also serves as an introduction to the important topic of the relationship between structure and behaviour.

Participants believe that this work plan makes them pay greater attention and intensify their reflection, both in decision-making and in observing the results obtained and looking into their causes (9).

In both cases the response has been very positive and we have built up a data base with those individuals and institutions that have shown an interest.

b) By appropriate development of the necessary complementary material so that, once they have reached the required level of skill, the new trainers can carry out their task efficiently. In practical terms, this has led to the production of material for student and teacher, to make the job of the latter easier. This material is of various types (5):

b.1. Written documentation on Systems Thinking and applications (either original or taking other, already-existing material as a basis).
b.2. Models (both generic and real cases)
b.3. Transparent Box Management Simulators produced from our own models, and others adapted from already-existing ones which are generally modified to include new elements. These TBMSs are accompanied by documentation as proposed in the previous paragraph.
b.4. Sets of transparencies for the material mentioned in b.1. and b.2.
b.5. Presentation software, in place of the transparencies.

5. FINAL CONSIDERATIONS.

Having reached this point, we believe we have accomplished the objectives set out at the beginning of this paper, the first of them being to state our position respecting the questions raised there:

1. **We believe that transparent-box management simulators are the most suitable** and that further progress should be made along these lines, facilitating the search for causes and the systemic reflection involved therein. However, we also think that the

number and type of experiments carried out should be increased in order to compare the learning process obtained with TBMSs and with black-box management simulators. In this way we will one day be able to generalize on the conclusions reached.

2. In our opinion, in the development of MFSs **the huge advantages offered by the new information technologies must be exploited**, though without disregarding the possible risks involved in an incorrect use of them. This would facilitate the learning of Systems Thinking.

3. In accordance with the above, **we ought to intensify the training of trainers**, both within businesses and in the Universities. This should be accompanied, on our part, by the development of the support material necessary to facilitate the task of these trainers in their respective organizations.

In a context in which managers have very little time at their disposal and the number of experts in System Dynamics is also very limited, the importance of the questions raised above and the interconnections between them becomes obvious.

Secondly, we have also indicated the lines of work being followed by our group in relation to the topics mentioned. We intend to make further advances along these lines in the coming years even if, given our activity in other fields of University life, we are only able to devote part-time dedication to them. Unfortunately, as in many other countries, it is, as yet, practically impossible to live exclusively off System Dynamics and Systems Thinking. We hope that one day fresh winds will blow.

NOTES:

1.- The subject of the complexity of Social Systems and the problems presented in decision-making is featured in a number of studies. Among the most recent, the following may be cited: Bakken B. et al. (1992, p.167 ff.), Graham A. et al. (1990, p.100), Graham A. et al. (1992, p.103), Machuca J.A.D. (1989b (p.306-312) and 1992a (p.40-41)), Senge P. et al. (1992, p.139), Sterman J. (1989 a and b).

2.- For comments on this subject, see Graham A. et al. (1990, p.101), Graham A. et al. (1992, p.152), Machuca J.A.D. (1989a p.177 and 1992a, p.43).

3.- See Machuca J.A.D. (1989 p.178 and 1992a,p.43).

4.- G.I.D.E.A.O.: Grupo de Investigación en Dirección de Empresas Asistida por Ordenador [Computer-Aided Business Management Research Group].

5.- The material we have developed appears in the Annual Progress Reports for our EC Project 4632 Cb (GIDEAO, 1991 and 1992).

6.- There have been participants in some courses who have stated that it would be advisable to train the firm's management team as a whole in order to allow for the application of the knowledge the former have previously acquired in Systems Thinking.

7.- See, for example, Diehl E. (1992), Kemeny J.M. and Kreutzer (1992), Camara A. et al. (1993), Langley P. et al. (1993).

8.-This aspect was also stressed by Morecroft J. (1992, p.466 ff.) and by Isaacs and Senge (1992, p.194).

9.- We have been carrying this out satisfactorily, not only in the above-mentioned courses, which began in the year 91-92, but since well before that in:

* Doctoral courses on Economic and Business Decision-Making by System Dynamics.
* The subject of Operations Management in the fourth year of the Business Science degree course.
* A course on Financial Institutions in Spain for the Business and Society program, aimed at North American students studying in our Faculty for one semester.

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