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# The Challenge of Teaching System Dynamics in ITESM System: A Proposal for a Teaching – Learning Method

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**Abstract**

*This paper addresses the didactic of the course of System Dynamic after a redesign process at ITESM Campus Monterrey. Design elements, educative intention, general objective, didactic strategy, contents, evaluation system, and information technology in use are discussed. Implementation has been done using a technological platform based on Lotus Notes / Learning Space. Qualitative results of implementation are presented indicating the advantages in both directions: (1) learning by the students and (2) teaching-practice transferring by the teachers.*

Key words: system dynamics, didactic, redesign, teaching-learning method, information technology, ITESM.

## 1. Introduction

The goal of this paper is to expose the particular manner in which the course of System Dynamics (SD) has been redesigned for ITESM System in Mexico. Information technology, social values, teamwork, and collaborative learning skills are the key elements of the redesigned course.

ITESM System is an educative system, formed by 30 Campus, distributed all around the country, and giving service to more than 92,000 students. The system has as mission "to form persons committed with the development of their communities to improve them on social, economical and political issues, as well as being competitive in their own knowledge area. The mission include to carry out relevant research and extension for a sustained development of the country."

## 2. Antecedents

The course of System Dynamics is part of a nine-semester academic program for Industrial and Systems Engineering. The course is taken during the fifth semester. Prerequisite and support

courses are “Differential Equations” and “Systems Engineering in Organizations”, respectively. This latter provides fundaments of System Thinking practice to the students.

Traditionally, the teaching/learning process of the SD course was centered at the teacher, as the main motor for the student learning. After and from the proposal of the ITESM of redesigning the teaching/learning process in 1996, the process evolved toward a schema where the learning was centered at the student. A deep reflection was realized in every one of the courses looking for the strategies and techniques more favorable based on the nature of each course in particular.

## 3. Proposal of Redesign

For the course of System Dynamics, the process of redesign was very interesting. The reason was the demanding characteristic about the amount of practice using simulators for the student learning. This characteristic outlined the first big strategy: convert the traditional classroom into a learning laboratory. However, the redesign of the course was not only change in activities. A methodology for working in class was designed which implied to define:

- General goal of the course
- Educative intentions
- Contents
- Learning strategies
- Evaluation system
- Specific activities of learning
- Reviews and updates of bibliography

A redesigning process is considered complete when all the reflection and design are done and the results are implemented in a technological platform of information technology (IT). Lotus Notes/Learning Space was the selected platform for many courses including SD. In this IT environment, the students have access to relevant documents and supporting material of the course. They make use of electronic places for interacting in-group and where they discuss about topics previously prepared by the instructor. The access screen to the databases of Learning Space is shown in Figure 1.

Besides the fact of having the relevant information available in databases is very useful for the students, it is also a key factor in the *Transfer Process* of the practice among Campus of the ITESM System. Teachers are encouraged to request and adopt courses from different Campus. This policy allows teaching the course for first time without starting from zero in learning strategies and activities. Opportunities of customizing the course are given by allowing making changes according the context of the teacher and students.

This redesign process also demands a continuous training process to the teachers. Topics from tendencies on education in the XXI century to specific courses on the area of knowledge are included. Teachers accumulate an average of 480 hours in the training program, which make them candidates for recognition about the educational practice and an economic stimulus as well.


**Figure 1 View of Learning Space databases**

## 4. Redesign Results on the Didactic of the Course of System Dynamics

The redesign of the course of System Dynamics in Campus Monterrey starts in September 1998. By January 1999, the course was implanted in the scholar semester in two groups of 40 students. The results reached on the structure of the course after the redesign process are described as follows.

General objective of the course

The general objective relates the educative contents and the technical skills, which will be covered and developed along the course. The objective was defined as:

> *The student will be able of carrying out analysis and representation of real situations based on principles of modeling and simulation of dynamic systems, sensitizing different scenarios of the situations under study with the support of computational package of continuous simulation.*

Educative Intentions

The educative intentions are strongly linked to the Mission of the ITESM and thus the profile of the graduate who is formed. In this sense, it is pretended to provide the students not only of knowledge, but also of skills, attitude and values. The idea is not only forming experts in specific discipline but persons with values and commitment with their society. Following this line, the educative intentions were defined for the course of System Dynamics as:

*It is intention of this course to achieve in the students, the development of a culture of teamwork since as Industrial and Systems Engineers will require to confront complex problematic situations, which in an individual form would be very difficult to confront. In the same way, the students will require competencies to learn by their own, identify and solve problems, and in their roles of modelers, be honest and responsible.*

Conceptual Model of the Course

The conceptual model represents graphically the more important elements that form the content of the course. The course was divided in three themes according official analytic program. They are *Introduction to System Dynamics*, *The Concept of Dynamics System*, and *Modeling of Dynamic Systems.* The three of them have been labeled as *Philosophy,, Tools, and Application.* The arrows indicate the sequence, starting from the base of the pyramid, which denote that the next step requires knowledge of the previous one. The conceptual model is shown if Figure 2.


**Figure 2 Conceptual Model of System Dynamics Course**

Specific objectives of each theme

The specific objectives establish the thematic content that will be covered. For example, for the theme 1, the specific objective was defined as:

*That the students known the focus of System Dynamics and its main contributions making efficient use of the informatic and teamwork.*

The objective redacted in this form will give the direction to follow for designing specific activities of learning.

Contents

The contents of the course respond to the question: ¿what does the student have to learn in this course? Contents are classified in three categories: (1) conceptual, (2) procedural, and (3) attitudinal. Conceptual contents refer to the facts, concepts and principles. Procedural contents refer to the methods and procedures. Attitudinal concepts refer to the values of the international society, local community and individual. Instructional and didactic advisor take care of the alignment among general objectives, specific objectives and contents with the institutional mission. The main contents of the course are listed below.

**Conceptual** contents (from the analytical program of the course)

1. Introduction to System Dynamics: fundaments of System Dynamics; the concept of model; main contributions of System Dynamics.
2. The concept of dynamic systems: principles of dynamic systems, feedback systems, causal and block diagrams, mathematical formulation.

**Procedural** contents

1. Methods to construct System Dynamics models.

**Attitudinal** contents

1. Awareness about the responsibilities of decision makers in complex systems about the short and long terms effects.

Strategies of Learning

One of the most important strategies of the course is the simulation of roles. Example of this is "The Beer Game", key element which is played at the beginning of the semester. The strategy allows the student to learn by playing. Another strategy is exposition of themes by the teacher, important element in the process to clarify and share knowledge, key issues in each theme

Evaluation System of the course

In the traditional learning-teaching paradigm, centered in the teacher, the evaluation of the students was basically realized trough written exams. The final grade was integrated by the average of the exams and a final project with a weight of 80% and 20%, respectively. Now in the new proposal, every learning activity designed by the teacher and realized by the students is graded. The final grade is then integrated by 50% related to learning activities and 50% related to exams in both manners written and using computer simulations. In this form, it is not just discretely evaluated a final product but it is continuously evaluated and monitored the progress of the students.

It is important to mention in this section, the role that plays the coevaluation among the students having high teamwork loads. At the beginning of the semester, students are requested to elaborate their own team conduct code. This code explicitly includes, among other issues, the criteria that will be used to coevaluate teammates. Participants of the team recognize the value of the work and participation that every one generates.

Specific Learning Activities

The big change caused by applying the educative strategy of simulation of roles was to convert the traditional classroom into a learning laboratory. Learning activities were adapted and supported by several sources. In basic concepts, among others, by The "System Thinking Playbook"(Booth and Meadows, 1997); in tools, by "Systems Thinking Basics" (Anderson, 1997); in causal and block diagrams, "Road Maps" published at Internet by the MIT. This material is considered highly worthy for us due it combines fundamental documents on concepts supervised by Prof. Jay W. Forrester and others on highly illustrative exercises for self-learning.

The learning laboratory takes actions after the theme 2. The laboratory requires a computer with an installed simulation package. Since several years ago, a policy that has been running at ITESM is that new students have to have his own Laptop. In this form, students guarantee the capacity of having access to the databases of their courses. When the students arrive to the course of System Dynamics, currently 80% of them are able to bring a computer to the classroom. The laboratory is then relatively easy of implementing and guided practice with the computer simulator can be realized at each class if it was specified. Later students are responsible of keep independently practicing.

The culminating learning activity of the semester is the final project. Students practically work 3 out of 5 months of the course in this project. One of the most enriching experience obtained on final projects has been the modeling on problematic situation in Mexico. This model demanded the self-organization of teams to take the responsibility of modeling critical subsystems. For example, one team considered education and others economy, industry, commerce, among others, until considering the complete puzzle according the group. The teams define by themselves a general coordinator and area coordinators in order to make the project manageable. At the end, they handed in a complete report for every subsystem and analysis of scenarios of the complete model.

Review and update of bibliography

The nature of the course continuously demands the search for new supporting material to include in the bibliography. Currently, (Sterman, 2000) is being studied as an option for a textbook of our students.

## 5. The tangible product: The Data Bases of Learning Space

The transference of the know-how of the course would not be practical without the support of information technology (IT). IT allows having the course completely documented for purposes of adoption by interested teachers or course operation by current students. Figure 1 shows the screen of access to the four databases: *Schedule*, *Media Center*, *Course Room* and *Profile*. Additionally, this technological platform offers another database, which allows the design of different sort of exams to evaluate students on line. The organization and contents of the four databases are described as follows.

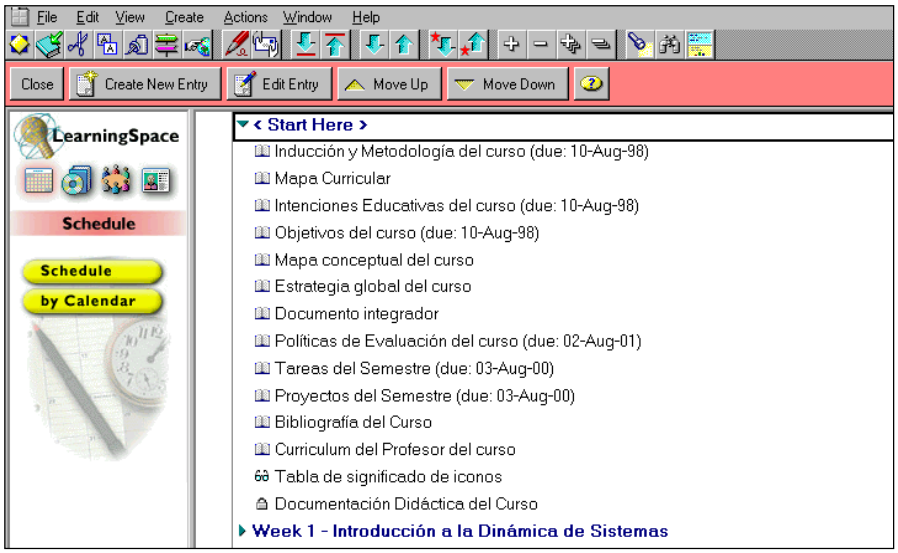


**Figure 3 Schedule database**

## Schedule

This database is the heart of the course. The *Schedule* structures the elements that provide meaning to the course. Examples of these elements are the general objective of the course, educative intentions, strategies, evaluation system and the detail of the contents session per session. This latter indicates the learning activities that become action before, during and after class. A view of the Schedule database is shown in Figure 3 and the information of one session is shown in Figure 4.

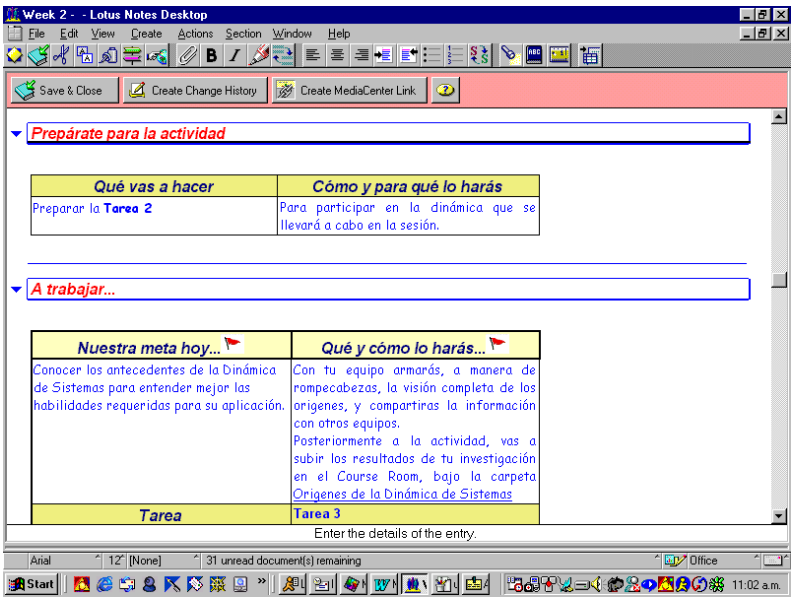


**Figure 4 Detail of one session in Schedule**

Media Center

This database concentrates the documents and supporting material that will be used in the course. Specification of homework and projects, paper that support fundaments such as selected Road Maps, presentation files used by the teacher in class. Media Center is used also as a space to expose grades of the course.

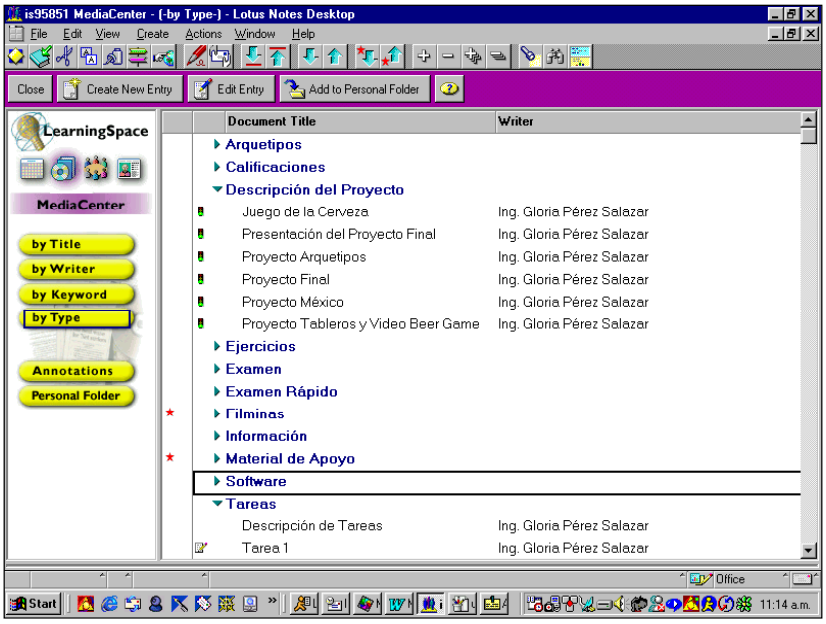


**Figure 5 Media Center database**

Teachers have found it as a rich repository of relevant material where they can save, sort and retrieve practical exercises, specifications of final projects since files can have assigned a password. In this sense, teachers can construct the history of the evolution of final projects developed in different semesters. The screen of Media Center is shown in Figure 5.

Course Room

This database offers two important spaces of interaction. The first one deals with the environment where the students have discussions. Some discussions may have the teacher as referee. The most interesting discussions during a semester are related with "The Beer Game." The discussions are organized in such a way that students with same role can share their experiences, points of view and learning. Each team has to upload a brief comment that resume the learning perceived as function of the distribution chain. This discussion is the final activity. The second space is dedicated to receive homework from the students and send feedback from the teacher. The current course has a hybrid model with both types of interaction. Organization of Course Room Discussion is shown in Figure 6.

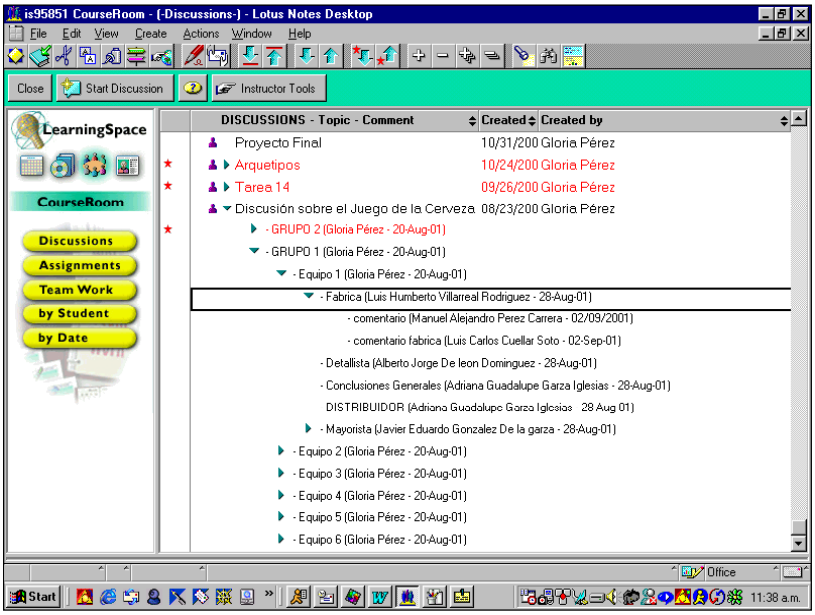


**Figure 6 Course Room database**

Profile

On one hand, this database has an objective to provide an environment to the students in where sharing their profile. The participants of the group have access to the information such as telephone number, address, hobbies, and previous background and labor experience. This information is useful for teamwork when some of its elements has to be found. On the other hand, the database allows the teacher to send feedback about the performance of each student. The screen of *Profile* database is shown in Figure 7.

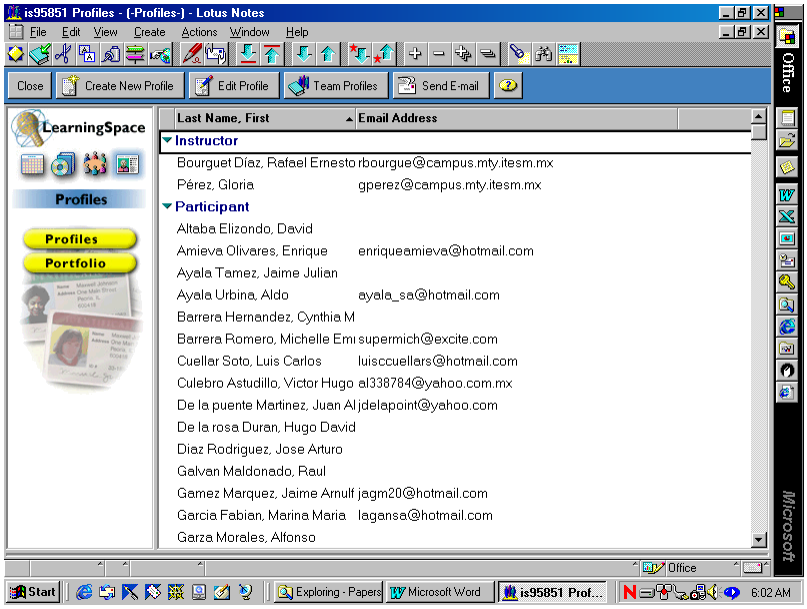


**Figure 7 Profile database**

## 6. Observed Qualitative Results

According to the students the traditional method of teaching was monotonous and boring compared with the current method. Also with the current method, the participation of the students is more active, demanding more work previously to the class session, making students more responsible of their own learning. The most important result has been observed in the quality of the final projects developed by the students. It is perceived a higher degree of comprehension and skills of the concepts related to the design of models with greater complexity at every time. An example is the project mentioned in the Learning Activities section on problematic situations about Mexico. The students really live the concept of System during the realization of the model. Certainly, the obtained model requires more effort in testing and validation to increase the model reliability. The valuable issue of the exercise is that 40 persons developed the model. They had to define the project direction that should be taken in order to obtain an integrated complete model. The sector design diagram of Mexico model is shown in Figure 8.

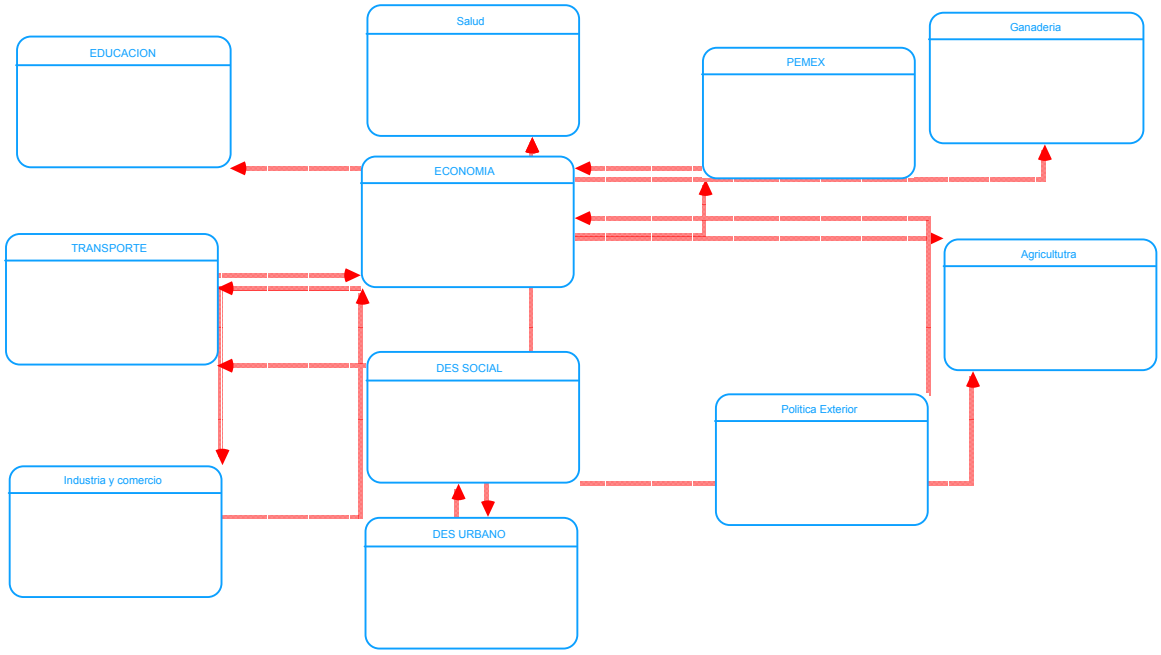


**Figure 8 Sector Design of Model "Mexico"**

## 7. Conclusions

We are convinced that the combination of theory and practice inside the classroom has been one of the most enriching experiences as well for the students as for the teachers. Students begin the course of System Dynamics with a feeling of insecurity due to an initial perception that the class is difficult and complicated. However, this feeling is vanished insofar as students get into the course rich in learning dynamics and practical exercises. The course does not become easy but also the students get confidence to face the challenges that are demanded by the class.

We are aware about the relevance of using information technology in class nowadays. However, IT is just a medium and not an end. The successful or failure of the course still depends on the teacher skills to involve students in the search of their own knowledge.

Currently, the authors are involved in the design and development of an institutional final examination of System Dynamics. The examination will be applied to 700 students in May of this year. Students are from all the Campus of ITESM System. The goal is to evaluate the homogeneity and depth of the knowledge students possesses on System Dynamics.

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