The Introduction of Simulation as Teaching and Learning Tool

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ABSTRACT: *This paper relates an experiment that seeks the introduction of simulation as teaching and learning tool to the students of Production Engineering and Business Administration courses, and for recycle process of executives, to offer to the student the opportunity to verify, for its own initiative, the acquired knowledge and its applicability. It is intended, besides presenting the method described above, to define a methodology of analysis of the learning levels reached by the student, starting from the application of that technique, in comparison to the traditional technique.*

KEYWORDS: *System Dynamics, Learning Organization, Simulation, cognitive process*.

INTRODUCTION

Specially, in the last two decades of this century, we attended the exponential growth of the technological progresses, that reached without restrictions, all the areas of human activity and the extention in that the mercantile and productive processes become more complex and dynamic, the work is due to the learning, so that the organizations stay competitive (Senge, 1998). By one hand, that fact leaves clear the need of permanent recycle of the active staff of the organizations, turns extremely hard the task of development a new staff, that still belongs to the universities.

In the phase of formal acquirement of the knowledge, the studen comes across a several range of disciplines, that cover several organization fundamental concepts, operational and managerial concepts. Such concepts proceed as a certain flow, because they have a pedagogic and operational necessity. But, this concepts, won't necessarily form the student the appropriate general idea that what is the Organization.

If we start from the premise that formal knowledge aims to transfer the student the interpretation power of managerial complex system, we will reach the conclusion that a student that doesn't have any effective knowledge on the system will delay from four to five years (relatively to the chosen course) to interact efficiently with that complex system.

On the other hand, we can imagine that the knowledge transference gradually joins value to that semiprofissional, even so, according to Koliver (1997): " The acquisition of abilities in graduation... during the period of basic formation, that is, of apprehension of knowledge, is illusory, for the simple fact that the student doesn't still possess the global vision of the profession, nor at least as regards to knowledge ".

Supposing that before the end of the course it is improbable that the student counts with the necessary reasoning for systemic interpretation of the system company. It also seems that it is very impprobable that the systemic reasoning is obtained automatically after the conclusion of the disciplines. This problem occurs because the studend can not make the relatioship among the disciplines learned during the course. The internship (student that goes to the organization to practice) that could fill this imperfection doesn't usually get sucess, and this happens because interners don't execute real tasks on the internship that would help them on the learning process. In this process of college learning the things get worse while the student accumulates all these imperfections along the years, and this accumulated imperfections doesn't allow the student to reach the highest performance that is expected by the society, and then it turns to a gap of learning. This gap is separeted in two levels of professional graduation. By one hand, the very each part of individual view, and by the other hand this systemic desired view.

We consider that to minimize this gap above described the student should have the opportunity to verify his own intiative of applicability of his acquired knowledge in the industrial complex system, attributing not only the possibility of that applicability view, but also allow the student to trace the underlying variables in the purely cientific sense of action interpretation, and their possible causes. That picture can only be gotten starting from interdisciplinary activities, that permeate the knowledge areas you correlate, extracting of them the essence of the systemic learning. It should come up of these activities the mental models that will assure the capacity to dominate the principles, so that the aimed results are produced. Those changes in the mental models of short period will accumulate, and they will reflect slowly the changes in the rooted faiths of long duration. This can

generate alterations under the perceptions built by those people, as part of its daily processes of reasoning (Senge, 1997).

In that way, it is possible to verify that the new professional's vision should not be limited to the lived experiences. They should look for a vision of the future to be created, conceiving it in the present time, as if in fact it happened. That effort of an objective shows where we want to go, and what will be when we arrive there. It should be given to the student the possibility of training his capacity of systemic analysis, as well as the interpretation of those analyzed systems is not static, but dynamic, and its interaction with them won't be virtually the same in elapsing of the time Zambom et al (1998).

In order to organize this paper, it is presented first of all, the Use of modeling and simulation, as well as the system dynamics methodology. After those concepts, it will described the singular experience that de Industrial Dynamic Laboratory (LDI) have in Production Engineering Department (DEP) using simulation during the courses, and then its analysis and finally the conclusion of this paper.

THE USE OF MODELING AND SIMULATION

The research on this paper relates the use of Simulation to support the structuring of problems in group and of cognitive processes as main tool.

The modeling based on system dynamics, on one side, it can be seen as a mapping process that uses graphs, diagrams, words and simple and friendly algebra to activate and to capture knowledge of people's groups that act as team. On the other hand, it can be seen as a group of systematized and developed knowledge to organize, to filter and to structure the vast knowledge that a team shares. In any way, they represent the microcosm of the reality and learning atmospheres where the people can test the challenge and rebuild its own mental models.

The methodology System Dynamics (Forrester, 1961) they have been used basically to denominate a group of methodological instruments that they analyze, for example, how the operational politics of a company interact, with its vendors and its customers, to determine its performance in the time. In a general situation, they constitute a group of structured knowledge to analyze and to understand as interdependents agents of a system in the course of the time to determine the performance of the system itself.

System Dynamics modeling works with theory of feedback information, which supplies elements for mapping and construction of archetypes of systems, in terms of diagrams, equations and programming language, for development of computacional simulation. It also makes use of the comportamental of decision theory, to describe, to define and to identify processes of empiric decision (Sterman, 1987,1989). The company and its atmosphere are seen as a group of agents whose decisions and actions affect each other. Each agent is represented by a function of decision that allows entrances and exits that can be so much information as action. The information that an agent receives depends inside on its position of the organization and other factors such as objective, award form and the way of counting the results of the organization. In synthesis, that approach worries in to analyze how the agents of a system interact, and to show how they can intervene for its alavancar performance.

Periodic European Journal of Operational Research dedicated in 1992, under the title of Modelling for Learning, the edition 59(1), only to show how modeling and simulation can be used for generation, development and transmission of knowledge. We are giving the first steps in this direction and we presented, in a summarized way, some experiments accomplished by the Industrial Dynamic Laboratory (LDI) of the Federal University of São Carlos (UFSCar).

THE EXPERIENCE IN DEP/UFSCAR

The Industrial Dynamic Laboratory (DEP-UFSCar) uses several simulations to transport theoretical subjects, approached in some disciplines, from expositive classes, into the "reality" of a simulation controlled in laboratory (microworld). Those controlled simulations, in its majority, don't need the computer for their development, but for the tabulation of data and supply of the analysis reports on the participants performance.

All the simulations have has their central point the work in team, considering that starting from the cooperative work solutions should appear. In previous works (Zambom, 1998) non-cooperative work situations were discovered derived from some specific simulations to detect such pictures:

> *" ...becomes patent the concern in establishing internal strategies for its enterprise, although there were wide warnings that the costs should be minimized by the chain of supplies in a global way. More then half of the agents (58%) preferred to center in internal business conduction strategies, to the step that 18% of the agents just preferred to opt for the strategy of the observation, with the objective of synchronizing its movements with the one of the partners ".*

Such simulations, specific for the treatment of the subject "to learn by learning" are basic and they are given to students as the first contact with the methodology, in the sense of showing them the flaws usually contained in the mental models used.

All the simulations still possess specific characteristics that contemplate the visualization possibility of seeing all the variables included in the problem (systemic vision) and a " formula" doesn't exist for the solution of the subject, since the answer originates from the individuals' relationship and not from a partitioned form.

Next, you find described in a brief way, the models used in the simulations:

Beer Game

It is constituted of a manual simulation, of which four agents participate, composing a production chain. Those agents are: maker, wholesaler, distributor and retailer. Beyond of those agents, incorporated by the students, it exists a raw material vendor and a customer for the final product, both incorporated by a monitor or facilitator. The approached subject is typical of planning and control of supplies. Through this simulation, it tries to show the interdependence of the actions taken by the participants how these interfere in the conduction of the business of the chain as a whole in a horizon of time that extrapolates the present. After the simulation, it is accomplished a dynamics that has for objective to show the consequences of the lack of systemic vision and of the problems that regrets of the non use of the personal mastery (Senge, 1990), that consists of each one of the members of a team stop using its own pictures of vision of the world, to think of colaborative form.

Supply Chain

It is constituted of a manual simulator of two chains of supplies. Its members (a total of eight for team, besides a monitor), starting from negotiation, try to accomplish agreements and alliances, determining periods of delivery of the products produced by the chains. This simulation turns possible to accomplish a study of the importance of the communication and of the negotiation between the links of the production chains and distribution. This simulation, derived from the Beer Game, tests the capacity of the individuals submitted previously to that simulation for the colaborative work or in team (personal mastery).

ERP

This model is constituted by a manual simulator of a ERP system. It involves the team work of two participants' and a coordinator. It is composed of the ERP modules for control of the " factory " ground and the administrative section. It tries to show, with the application of this simulation, the importance of information coordination. Its objective it's to focus the systemic vision, proving that not always the sum of the positive results obtained in each managerial department, overcomes the global result of the company.

Working Capital

It consists of a simulator of an industrial company. Formed by four sections (marketing, sales, production and financial), consequently, of him participate four trainees, besides a monitor. The objective is to evidence the dynamics of the working capital administration. This simulation purpose is to stimulate the trainee into processing its analyses starting from the systemic reasoning , in way to contemplate all the important variables, included in the process of financial administration.

Gantt

This simulation involves the typical subjects of the production administration. The activities are accomplished by individuals' couples, helped by a facilitative agent. Supplies related questions, involving purchases of raw materials and allocacion of machines is part of the simulation. The participants have as objective to take care of the provisioning of the factory, allocating machine resources and raw labor to assist the largest possible amount of requests. Becomes possible, in that way, to offer a wide vision on the problems of production administration, not just involving taking of decision with relationship to the resources fabris, but also with relationship to the coming financial resources of the sales.

Oligopoly

This simulator, through the competition among companies (formed by 4 individuals' groups, besides the monitor), it facilitates to the participant contacts with the process of determination of prices of sales of the marketed products. Of the manipulation of that variable, it results the financial result and the demand of the company. The winner team will be that which will obtain the best financial result, after a certain time.

Those simulations are accomplished as complement of disciplines or as extension activity for the graduation. The time of simulation varies from 4 to 8 hours, including the dynamics accomplished after the simulation.

The accomplished sessions involve four to eight groups of participants in general. The simulations begin with the systems in balance. The first four interactions of the simulation are used to familiarize the individuals with the mechanisms of the sequences of activities to be executed.

It is initially announced that the simulation will last a specific number of interactions, that can be weeks, days or months, however, to avoid strategies determined by the end of the game knowledge, that initial number of interactions is not necessarily respected. The simulations can be interrupted in a premature way, when the system meets stability, that is to say, when the teams won the problems initially placed.

Starting from those simulations, manual or electronic ones, with the aid of the computer, a offer is given to the student or trainee, that is to say, the opportunity to verify by its own initiative the knowledge acquired in the managerial complex system, attributing it not only the possibility of visualization of that viability, but also of tracing the underlying variables, in the sense purely scientific of the interpretation of the action and of the possible causes, that happened from that action.

To the student is given the possibility of training a non fragmented analysis approach, as well as the interpretation that the analyzed systems are not static, but dynamic, and its interaction with them won't be virtually the same in elapsing of the time Zambom et al (1998). That atypical approach of the teaching process, originates firstly from the cognitive school, mainly in reason of the statement that the proposed method involves permanent creativity, the man's joint analysis of himself and the world, though, they are joined to the process, some characteristics of the behaviorist approach, in reason of the employment of "experiments". The simulations, however, don't possess purely mathematical logic, but they mediate among quantitative and qualitative subjects. It is still added, the emphasis in the interpersonal relationships, with team work in the simulations, and the teacher's image acting as facilitator, typically humanists values.

ANALYSIS OF THE SIMULATION EMPLOYMENT

To characterize the deficiency of the formal teaching and the challenges to be faced by the educators in the next century, the simulation method developed originally by Forrester will be used in this analysis (1961). The learning can be represented as a process, activity or flow and each one of them is related to an accumulation type or storage. We presented, in the Figure 1, an archetype of the global process of learning where we identified four learning processes: (1) accumulated knowledge (2) rebuild knowledge; (3) rebuild knowledge capacity and (4) share knowledge capacity.

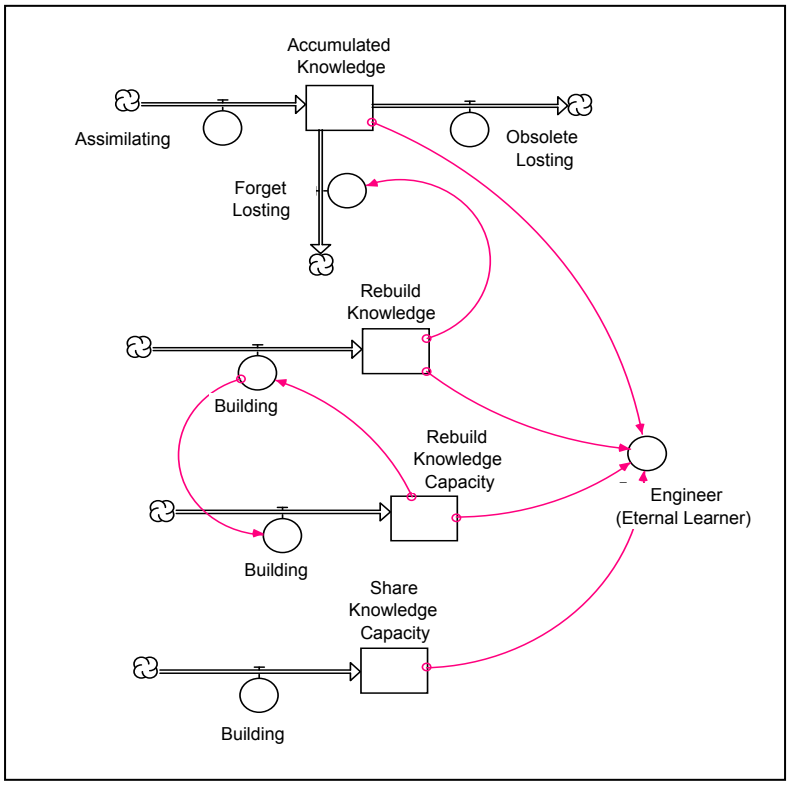

Figure 1. Complete Archtype of a Learning System.
Richmond & Peterson, 1992.

The learning process, dominant still today in the traditional teaching, it is based on the assimilation of knowledge. That process is represented in the superior part of the Figure 1, where the content that is being assimilated accumulates in a stock represented by a rectangle that expressed the accumulated knowledge. The activities are defined by the flow symbol and, in the case, they represent expositive classes , lectures and readings, which feed the knowledge stock. That is to say, through these activities, the content is deposited in the students' mind, where it should be stocked in their memory registers to be later acessed when requested.

The diagram of the Figure 1 also expressed the largest problem of the assimilation based learning. The diagram presents two escape flows through where the assimilated knowledge drains of the stock. From one of them, the accumulated knowledge is lost by the obsolescence and, in the other, from the own cerebral limitations, that is to say, from the forgetfulness. Naturally, so much the obsolescence rate as the one of forgetfulness is accelerated by the time passage. The knowledge in its ready form is perishable. To stock it it's expensive and it doesn't guarantee its readiness and, even if it is available, it may be no more necessary in the moment it was requested.

The second process it's just below the first and alternatively it could be called "Process of knowledge development", because it involves an active and not passive posture as in the first. In him, the students aren't even absorbing information passively nor assimilating the knowledge of someone regarding a group of relationships. Instead, they are themselves discovering and interpreting a group of relationships. The nature of this process is inherently active and creative.

The most important characteristic of this last method it is that, by means of him, the students tend to retain for much longer that they learned - to such point that it justifies, in the diagram, no-representation of the escape flow "forgetting". Even so, the fact of facilitating larger retention is not the largest virtue of this method. Its main virtue is to work with the "operative knowledge". In this process, means are supplied for the student to create again something that, in a certain way, it was already created before by someone. This experience serves not only to understand the problems in itself, but also to develop more widespread mental models than can be transferred for another areas of the knowledge, besides that one inside of which the subject is being treated. The great problem of this process is that it cannot do without of the capacity to build knowledge that, by itself, can be developed by means of the third process, that we denominated process of development of the capacity of building knowledge.

In some of the disciplines of the superior courses, such as Mathematics, Chemistry and Physics, the knowledge taken to the students already constitutes a group of relationships discovered, already created, or problems already solved by somebody. The most promising attitude in those cases would be to develop methodologies where that knowledge would be recreated by the students. However, this demands a certain preexistent creative capacity from the students, that, for that matter, demands the practice of the fourth learning process.

In the Figure 1, this process proceeds just below the previous. In him, the stock "capacity to develop knowledge" is would be what was being built, something that can only be developed by the constant practice of the creative activity.

Finally, we can speak about the fifth process: " building the capacity to share knowledge". That "capacity" allows the students to share the developed knowledge, in way to allow them to recreate that knowledge for themselves. She impels all the other ones because it forces the deepest discernment and it qualifies other to gain profit of the benefits of the capacity of thinking developed and it involves the communication capacity. That process is represented in the inferior part of the Figure 1.

In this last process, the abilities that fill its stocks are different from the previous ones. The abilities demanded "to divide" the knowledge indeed are quite different from that one necessary "to build" knowledge. Among other things, the ability to share knowledge is also called empathy - of the Greek empátheia, that means "tendency to feel what would feel case if it was in the situation and circumstances tried by other person".

Those that possess a well developed capacity for "empathize" are, in general, very respected by other people and they receive more attention.

In synthesis, the Figure 1 shows the "Stock of Reconstructed Knowledge" helping to stop the escape flow, that is to say, the " forgetfulness ". The practice of reconstructing knowledge supplies to the student means to maintain its Accumulated Knowledge. The Capacity to Develop Knowledge serves as a potential to build knowledge, while the activity "to build", for its time serves as a basic activity to develop the capacity to build.

The most important element of the archetype in the Figure 1 is our future agent transformer, technically represented by the conversor - Engineer ", the element that appears with the subtitle of - Eternal Apprentice.

The conversor " eternal apprentice " possesses four " imputs ". Two stocks of Capacities (potential abilities) and the stock of " reconstructed " Knowledge and " accumulated " Knowledge (ready and available knowledge). The logic that is expressed in the archetype of the Figure 1 is that, so that the formed individual is in fact an agent transformer, he should possess significant capacity empática to drive its actions in a systematic and appropriate way, associated to the significant capacity to build new knowledge as the world and the circumstances demand it. In addition, it should also stop a ready and available group of knowledge, that enables it to act momentarily and in an effective way, without he/she necessarily has to do use of the other stocks.

In that aspect, we believed that the simulation, in the way as placed in the previous topic, it can come to contribute in a decisive way in the complementation of that learning process, endowing the individual of capacity of the capacity of sharing knowledge, for the practice of the work participativo and colaborativo in group, besides endowing it of the capacity to develop and to fasten the knowledge

CONCLUSION

In the whole world, the focus of the Formal Education System is in the flow that feeds the first two stocks in the superior part of the Figure 1, that expressed the concern with that the student accumulates a certain amount of "Ready Knowledge" and "Finished Knowledge", in detriment of the development of abilities that would turn it much more capable for its self-accomplishment as a to be creative and transformer.

The great challenge for higher education in the next century it will be to develop and to use teaching methodologies that can serve as base for a citizen's formation that would enable him to use the knowledge to face creatively the problems of the society. In that sense, the teacher should go back its attention mainly to the last three Flows linked the Effective Citizen directly. It should be worried in as to motivate, to stimulate the use and the instrument development, in the several disciplines, that they can impel the construction of the three associated potentials directly in fact to the a citizen's formation, an individual capable to continue learning during the whole course of its life.

The Industrial Dynamic Laboratory (DEP-UFSCar) has been dedicating himself to the research of several simulation methods and development models that it has been altering the traditional process of teaching. We believed that the application of System Dynamics methodology, through the use of its tools, as the development of archetypes and posterior simulation, can contribute above to the solution of those defined lacks.

However we are still looking for an effective method to check that hypothesis and for so much, we are constituting a studies multidisciplinary team , composed by engineers, psychologists, sociologists and educators, that will have as fundamental objective to propose a method adapted to analyze the sceneries previous to the beginning of the application of that methodology in comparison to the sceneries obtained by the application of the methodology. Our goal is, to quantify the improvements obtained here with the use of the process described. The analysis works will be offered starting from future publications.

As well as in the past, when the resources were structured with views to the real needs of that economic moment, today, we should rethink the original systematic from which such courses were conceived, attributing them the flexibility demanded by the new paradigm, checking concrete subsidies for the interpretation not only of the present occurrences, as well as for the anticipation of the future occurrences, attributing, through the study of the dynamics of the organizacional processes, also the dynamism of the educational process. The effectiveness of the higher education next millennium will be directly linked to its capacity to approach the process of formal learning of the process of the organizacional dynamic, in way to give the recently-formed professional, the maturity waited by the society and the labor market.

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