Improving Strategic Thinking in Management Education with System Dynamics based ILEs: Reflections on a Case Study

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ABSTRACT

Over the past few years there has been an increasing interest in using computer simulation models to create *Interactive Learning Environments* - ILEs, for management education. Particularly when combined with System Dynamics simulation models, ILEs have proved their validity in a variety of different fields. Starting from these considerations, this paper focuses on the use of System Dynamics based ILEs for processes of individual learning, presenting and discussing the main features of a case study related to service quality management. The effectiveness of the ILE was assessed through a computer based experiment run in a master-course classroom. The paper shows that the ILE supported players to learn to: a) balance the growth of demand-side and supply-side resources; b) simultaneously control tangible and intangible resources; c) take into account the presence and the effects of time-delays; d) develop and apply policies, understanding the short and long term consequences of their decisions.

KEYWORDS: Interactive Learning Environments, System Dynamics, Individual Double Loop Learning, Management Education.

1. INTRODUCTION

There is an increasing interest in combining computer simulation models with other traditional teaching approaches (e.g. case studies) in order to create learning laboratories, named *Interactive Learning Environments* (ILEs) or *Management Flight Simulators* (MFSs), for management education[1].

When embedding System Dynamics simulation models such Interactive Learning Environments have proved to be particularly well suited to provide the basis for meaningful learning experiences about the relationships between the structure and the dynamics of complex domains in a variety of different fields.

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[1] *Interactive Learning Environments* (ILEs) are computer based simulation games, often built on real world cases. Also named "Microworlds" (Papert, 1980), "Virtual Worlds" (Schön, 1983), "Learning Laboratories" (Senge, Sterman 2000), "Computer-Based Learning Environments" (CBLEs - Isaacs, Senge 2000) and "Management Flight Simulators" (MFSs - Sterman 2000), ILEs are made of two interrelated parts, a mathematical model and an interface through which interaction takes place. The users take on the role of decision-makers within the system and are called to face complex problems in different scenarios.

Starting from the previous considerations, this paper aims to demonstrate that a System Dynamics based ILE may be effective in sustaining processes of individual learning in MBA courses (section n. 2). In particular, this work presents and discusses the main features of an ILE based on a case study related to service quality management.

To provide evidence of the effectiveness of the ILE for learning goals, a computer based experiment was organized. The key features and results of the experiment are subsequently reported (section n. 3).

As a whole, the paper shows that the ILE helped the players to learn to: a) balance the growth of demand-side and supply-side resources; b) simultaneously control tangible and intangible resources; c) take into account the presence and the effects of time-delays; d) develop and apply policies, understanding the short and long term consequences of their decisions.

From a behavioural perspective, the paper shows that the process of individual learning, the development of the different mental models of the learners and the gaining of a deeper understanding about the business environment are some of the results the experiment allowed to reach.

2. Facilitating individual learning with computer-based environments

In order to be efficient and successful organizations as well as individuals need to continuously improve their abilities and skills, acquiring new knowledge and operationalizing it, that is to say, they need to *learn*. However, learning implies to sustain and complete an articulated process in which several tasks must be performed and many psychological aspects need to be properly considered. Thus, designing learning projects implies to rely on a solid learning theory and on suitable learning tools/instruments.

Subsequently, this section presents some considerations on the role that computer-based environments (particularly in the form of System Dynamics based simulators) can play in fostering processes of individual learning, addressing the following topics: the concept of learning and the role played by "mental models"; the main features of Kim's Model of Individual Learning; the key elements for learning with "virtual worlds".

2.1. On the concept of learning and the role played by mental models

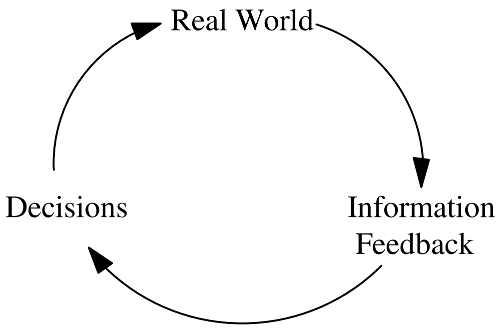
Sustaining and achieving learning is not easy. First of all, what does "learning" mean? And second, how is it possible to gain new knowledge?

In principle, two specific aspects are usually combined within the concept of *learning*: the acquisition of new knowledge or skills/abilities[2] and the relevance assumed by experience/experimentation.

It is to note that all learning depends on feedback, since learning is usually seen as a classical negative feedback as shown by the figure 1.

[2] For example, Kim (1993: 38) defines *learning* as "the acquiring of knowledge or skill", and Kolb (1984) states that "learning is the process whereby knowledge is created through the transformation of experience".

Figure 1 - *Learning as a simple negative feedback process*



Source: Sterman (2000: 15).

The figure explains how decision makers usually operate: they simply compare information about the state of the real world to various goals, perceive discrepancies between desired and actual states, and take decisions that should/will cause the real world to move towards the desired state. Such mechanism is often effective but reveals to be not sufficient when we analyse decision making processes in a broader perspective.

First, information feedback could be distorted by several factors related both to the environment in which we operate and to our way of thinking and making decisions[3]. Second, the analysis of real systems is frequently very complex because they are governed by a plethora of players continuously interacting[4]. These individuals have their own schemes and ways of reasoning/thinking/acting, i.e. their own mental models, and take decisions on the basis of their past experiences and their own tacit knowledge[5]. In this regard, Senge (1990: 23) emphasises that "the most powerful learning comes from direct experience. Indeed, we learn eating, crawling, walking, and communicating through direct trial and error - through taking an action and seeing the consequences of that action; then taking a new and

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[3] In this regard, it is relevant to note that social and economic systems are complex, dynamic, tightly coupled, governed by feedbacks, nonlinear, history-dependent, self-organizing, adaptive, counterintuitive, policy resistant, characterized by trade-offs. On these topics see J.D. Sterman (2000: 22).

[4] Therefore, information feedback about the real world is not the only input to our decisions, since decisions are the result of applying a decision rule or policy to information about the world as we perceive it. Note that decision-makers have bounded rationality (see Simon 1957) and limited information, and rely continuously on their own mental models, often biased by flawed cognitive maps, strong cultural assumptions and defensive routines/behaviour. In addition to that, it is also interesting to cite J.D. Sterman's thought (2000: 26) where he points out what follows: "humans are not only rational beings, coolly weighting the possibilities and judging the probabilities. Emotions, reflex unconscious motivations, and other nonrational or irrational factors all play a large role in our judgement and behavior. But even when we find the time to reflect and deliberate we cannot behave in a fully rational manner (that is, make the best decisions possible given the information available to us)". On these topics also see Cyert, March (1963).

[5] The concept of "tacit knowledge" is particularly relevant. Indeed, a great part of our knowledge and information is stored individually inside and is frequently hidden and not formalised. As Nonaka, Takeuchi (1998: 218) state, "tacit knowledge is personal, context-specific, and therefore, hard to formalize and communicate. «Explicit» or «codified» knowledge, on the other hand, refers to knowledge that is transmittable in formal, systematic language". This eventually leads to consider how individuals behave and take decisions, having already mentioned that mental models are the basis upon which people act. In particular, it is essential to mention the "*the theory of action approach*" and the difference existing between two typologies of theories of action, named *espoused theories* and *theories-in-use* (Argyris, Schön 1978). For further details see: Polanyi (1966); Argyris, Schön (1978); Nonaka, Takeuchi (1995).

different action. But what happens if the primary consequences of our actions are in the distant future or in a distant part of the larger system within which we operate? We each have a «learning horizon», a breadth of vision in time and space within which we assess our effectiveness. When our actions have consequences beyond our learning horizon, it becomes impossible to learn from direct experience. Herein lies the core *learning dilemma* that confronts organizations: *we learn best from experience but we never directly experience the consequences of many of our most important decisions*".

In sum, two issues need to be addressed in the design of any learning project[6]:

1) which is the learning theory we rely on?
2) which are the tools/instruments we use to facilitate the acquisition of new knowledge and to support learning?

Regarding the first question, the following section briefly presents the main features of Kim's model of individual learning[7]. Regarding the second question, the paper refers to the use of computer based environments. In this regard, within the System Dynamics community it is largely recognised that simulation and gaming may assist managers and students in conceptualizing new information, eliciting a shared language, providing a structured way of thinking about complex problems; in brief, they may help people to learn about the world in which they operate. Further details are provided in the following paragraphs.

2.2. Kim's Model of Individual Learning

Many authors and system thinkers point out at the work made by John Dewey, who recognised the feedback loop character of learning, described as an iterative cycle of invention, observation, reflection and action (Schein 1992). Such framework was theorised by the so called "School of the Experiential Learning" (Kolb 1984). Starting from these premises, Daniel Kim presents a particular version of the learning cycle, based on Kofman's work.

First, the author clarifies that learning encompasses two meanings:

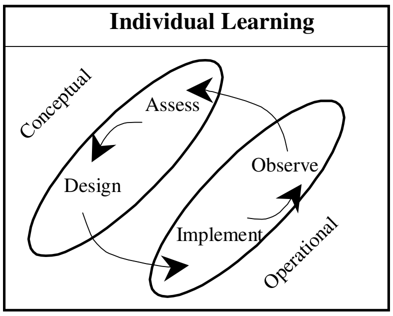
a) the acquisition of skills or *know-how*, which implies the physical ability to produce some action (*operational learning*);
b) the acquisition of *know-why*, which implies the ability to articulate a conceptual understanding of an experience (*conceptual learning*).

Based on these assumptions, Kim presents the so called "*OADI cycle*": Observe - Assess - Design - Implement, as shown below.

[6] Note that this paper takes into exclusive consideration *individual learning*.

[7] Many authors have studied individual learning and several theories have been developed, mostly by psychologists, focusing on stimulus-response behaviourism, cognitive capabilities and psychodynamic theory. However, many issues are still open since dealing with human beings and their mental models is a difficult task. For further details see Kim (1993: 37-38).

Figure 2 - *Kim's Model of Individual Learning (First part: OADI)*



Source: D.H. Kim (1993: 40)

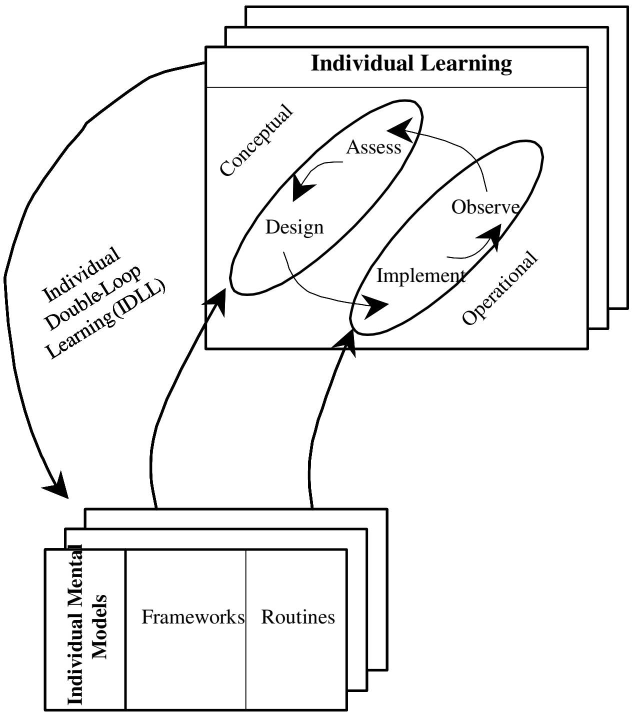
In this cycle, "people experience concrete events and actively observe what is happening. They assess (consciously or unconsciously) their experience by reflecting on their observations and then design or construct an abstract concept that seems to be an appropriate response to the assessment. They test the design by implementing it in the concrete world, which leads to a new concrete experience, commencing another cycle" (Kim 1993: 38-39).

As shown above individual learning requires to complete full learning cycles, each of them made by several tasks. However, this may be not sufficient.

Here is where *mental models* play a fundamental role, being individuals' view of the world, including explicit and implicit understandings[8]. In particular, the two levels of learning we have previously mentioned (conceptual and operational) can be related to two parts of mental models.

[8] *Mental models* are extremely relevant when facing complex systems, characterized by a large number of feedback loops and by the presence of delays and nonlinearities. "The term mental model means the conceptual model that each member of the management team carries in his or her head to explain the way the business (or more generally, the outside world) operates" (Morecroft 2000: 7). Furthermore, it "includes our beliefs about the networks of causes and effects that describe how a system operates, along with the boundary of the model (which variables are included and which are excluded) and the time horizon we consider relevant" (Sterman 2000: 16) On the definition of *mental model* also see Senge (1990: 9); Forrester (1995: 3); Vennix (1996: 21); Ford (1999: 3).

Figure 3 - *Kim's Model of Individual Learning (Second part: OADI-Individual Mental Models Cycle)*



Source: D.H. Kim (1993: 40).

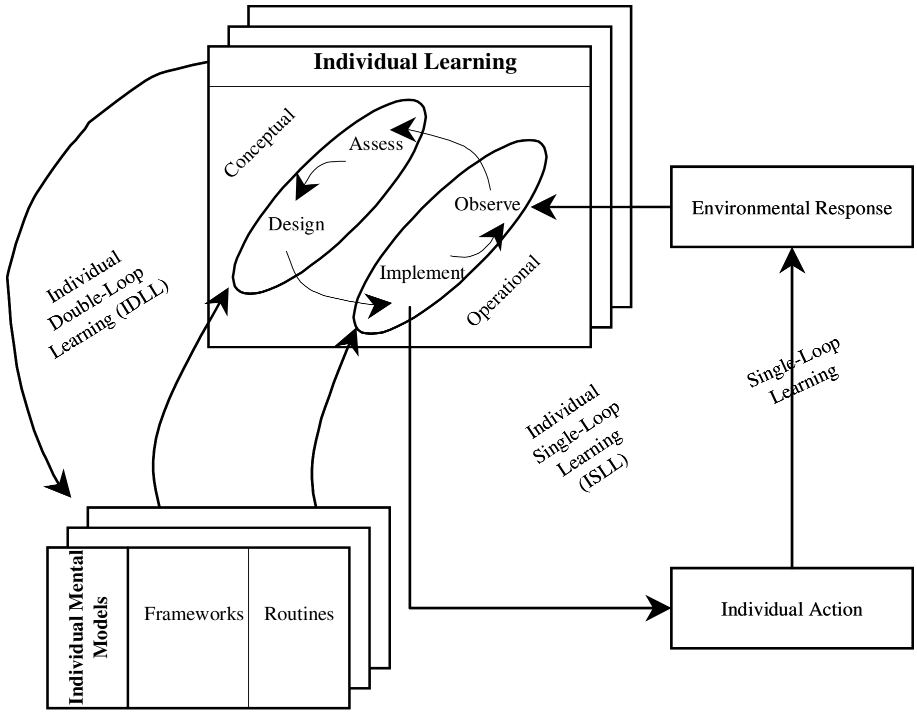
"*Operational learning* represents learning at the procedural level, where one learns the steps in order to complete a particular task. This know-how is captured as routines. (…) Not only does operational learning accumulate and change routines, but routines affect the operational learning process as well. (…) *Conceptual learning* has to do with the thinking about why things are done in the first place, sometimes challenging the very nature or existence of prevailing conditions, procedures, or conceptions and leading to new frameworks in mental models. The new frameworks, in turn, can open up opportunities for discontinuous steps of improvement by reframing a problem in radically different ways" (Kim 1993: 40). Thus, operational learning deals with the changes in the way we actually do things, while conceptual learning emphasizes the *why* of doing things, that is, it is related to the thinking behind why things are done in such a way[9].

Hence, the individual learning cycle is the process through which those beliefs change and those changes are then codified in individual mental models. In figure 3, the arrows going in both directions represent a mutual influence that makes possible such changes.

Last, the figure shown below clarifies how an individual relates to the external world.

[9] In other words, individual learning is captured in mental models in two different paths: a) operational learning produces new or revised routines that replace old or outworn ones; b) conceptual learning leads to changes in frameworks, leading to new ways of looking at the world and new actions.

Figure 4 - *Kim's Model of Individual Learning (Third part: OADI-Individual Mental Models-Individual Single and Double Loop Learning)*



Source: D.H. Kim (1993: 44).

"The diagram traces the process through which the brain assimilates some new data (environmental response), takes into account the memories of past experiences, comes to some conclusion about the new piece of information (individual learning), and then stores it away (individual mental models). After processing the new learning, one may choose to act or simply do nothing (individual action)" (Kim 2001: 20). This theory explains what makes possible to experience both individual single and double loop learning, that is to say, the framework of individual learning theorised by Kim is made of a (OADI) cycle of conceptual and operational learning that informs and is informed by mental models. Note that this is the essence of the *double loop learning* theorised by Argyris[10].

In sum, as Sterman (2000: 25) argues, "to learn we must use the limited and imperfect information available to us to understand the effects of our own decisions, so we can adjust our decisions to align the state of the system with our goals (single-loop learning) and so we can revise our mental models and redesign the system itself (double-loop learning)". Only in this way it will become possible to really learn and acquire new skills and knowledge.

[10] As Argyris (1993: 8) argues, learning can be achieved under two different conditions: first, learning occurs when there is a match between intended aims and results achieved; second, learning occurs when there is a mismatch between intentions and outcomes, such discrepancy is detected, corrective actions are taken and a match is achieved. Subsequently, these situations lead to two kinds of learning: *single-loop learning* occurs when matches are created, or when mismatched are corrected by changing actions; *double-loop learning* occurs when mismatches are corrected by first examining and altering the governing variables and then the actions".

This said, it is fundamental to identify which methodologies, techniques and tools may be taken into account in order to stimulate and foster processes of individual learning, especially when the intended learners are management students. In this regard, there has been a great debate on learning styles and educational methods over the past decades.

In principle, *education* entails to transfer to students specific skills and to increase their level of knowledge[11].

Note that during the last years *case studies* have been frequently used in order to combine most of the previous elements for HE (higher education) and management education[12]. Actually, a case study offers a synthetic way of looking at events, collecting data, analysing information, reporting results and infer new lessons about how to apply decision rules and policies. However, as Graham *et al.* (1992: 151-152) underline, "the case method has limitations. Chief among these is the impossibility of testing hypotheses the participants offer as to the effects of alternative actions. To evaluate the consequences of policies other than those described in the case, and even to attribute the actual outcomes to particular causes, one must conceptualize a model of the system described in the case and perform mental simulations to infer its likely dynamics. But people face formidable problems in formulating appropriate models of complex environments and correctly relating system structure or behavior".

It is our opinion that this situation opens up great opportunities for the use of computer based learning laboratories.

2.3. Learning with Virtual Worlds

Over the last two decades and particularly in the last ten years, thanks to advances in Information Technologies, computer models and computer based laboratories have proved to be powerful learning tools. In particular, very often computer-model based laboratories have been used to support strategic thinking, group discussion and learning in management teams[13].

The great advantage of these tools relies in their capacity to sustain processes of learning not achievable in real life. This is particularly relevant when such ILEs are created on the basis of a simulation model developed according to the principle of the System Dynamics methodology[14], that is well suited to analyse complex domains in which the decision-makers have to deal with dynamic and persistent issues, whose effects will be experienced in the long period and require to take strategic

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[11] A major classification of educational methods could be aimed at identifying at least some different kinds of learning, as follows: *auditory learning*, traditionally taught in students education, based on listening to instructions/information/lectures; *visual learning*, occurring through the observation of what it is supposed to be learnt; *experiential learning*, based on being engaged in hand-on work activities. All of them can make learning occur, although at different degrees and with a transfer of knowledge more or less persistent.

[12] As Graham *et al.* (1992: 151-152) underline, in management education "case studies are the cornerstone. The objective is to develop skills to 'think strategically', 'view the business as a whole' or 'adopt the perspective of the general manager'".

[13] As Dörner (1996: 8-9) highlights "computer technology allows us to simulate almost any complex situation we might wish to study, from the flora and fauna of a garden pond to the social interactions in a small city. The flexibility of computer scenarios allows psychologists and other social scientists to examine experimentally processes that were previously observable only in isolated cases. (…) Computer simulations also enable us to observe and record the background of planning, decision-making, and evaluate processes that are usually hidden. It is easier to isolate the psychological determinants of such processes this way than it is to investigate them retrospectively in the real world".

[14] On the principles of the System Dynamics methodology see Forrester (1961 and 1968); Richardson, Pugh (1981), Sterman (2000).

decisions often based on their own tacit knowledge and past experiences[15]. In particular, System Dynamics based ILEs proved to be effective learning tools when designed considering the following learning principles:

a) learning from experience is considered very relevant for human development (Lewin 1951; Kolb 1984);
b) learning occurs more easily when players are mentally active during the learning process;
c) double loop learning is more likely to occur through experimentation in virtual worlds (Sterman 2000) since it is possible to challenge and influence the mental models of the participants in a safe and free-risk environment, quickly completing the *unfreezing-change-refreezing* process as argued by Schein (1992);
d) transfer-appropriate learning can be achieved by helping learners to learn new information and skills in contexts as close as possible to those in which they will eventually need to use them (Tomlinson, Masuhara 2000: 159);
e) interacting with computer models, players usually use their tacit knowledge and improve their skills and abilities; in this way, new knowledge can be obtained more quickly and for conditions not observable in real life (Vennix 1996).

In brief, ILEs offer learning conditions that could not be found in the real world or using other educational tools. However, to reach all these learning goals, ILEs should also be designed in order to exhibit some key features.

1) *Transparency* - The idea underlying the concept of transparency is that if the relationships between structure and behaviour are clearly shown and are understandable and relatable to policy-making, it becomes possible to foster the learning process[16]. As well known, the relationship between structure and behaviour is at the very heart of the System Dynamics approach and is fundamental in constructional learning[17].
2) *Realism* - Pursuing reality means that the simulation environment should resemble as closely as possible a real-world environment although a delicate balance between realism and usability is to be found[18]. Hence, the key questions in designing an ILE are the following: a) does realism enhance

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[15] Many authors point out that System Dynamics represents a powerful methodology in order to investigate complex systems and foster processes of individual and organizational learning. Therefore, creating System Dynamics based ILEs for educational purposes is particularly fruitful when (Spector, Davidsen, 1998: 5; Graham *et al.*, 1992: 152): a) the domain is complex and dynamic; b) the environments under investigation are characterised by multiple feedback processes, time delays and nonlinearities; c) learning goals involve understanding the complexities of the subject domain well enough to identify key relationships among various system components and how these relationships account for the behavior of the system in a variety of situations; d) learners are most often either introductory or apprentice level students in the subject domain, or else they are practitioners with an admitted or documented lack of expert performance in managing complexities of particular systems.

[16] Alessi (2000: 180) refers to the transparency of an ILE in terms of *designing the degree of model visibility*: "some model parts may be visible and some hidden, and the degree of visibility may change or depend on learner progress. Visibility may be provided in different ways, for example, showing the stocks and flows in a flow diagram, showing the underlying equations, or showing a causal loop diagram. Parts of a model may be hidden at some times and made visible at others, depending on particular needs and objectives".

[17] Therefore, a direct access to the underlying model and equations (or at least to the CLDs) could significantly foster the learning process, also helping users in making a shift from a static and linear approach to a feedback approach.

[18] For instance, decision makers could be accustomed to read and get information from accounting-oriented spreadsheets and they could consequently benefit from having the chance to consult such reports during the simulation (Bianchi 2002:

the learning environment? and b) do too many graphics and reports overwhelm the participants' abilities to manage the ILE?

3) *No threatening environment* - The ILE must be not threatening for users and should: a) be "positioned not as an answer generator but as a useful vehicle for illuminating and communicating issues of importance" (Bakken et al. 2000: 247); b) represent an open and free-risk space where it is possible to develop skills, test policies and strategies, shorten users' learning curve[19]; c) develop forms of collaborative learning, weakening individuals' defensive routines[20].
4) *User friendly environment* - People usually perform better if they interact with a "friendly environment". This is particularly relevant since people own different computer skills and considering that some individuals could not be accustomed to interact with simulation models. Thus, the interface of the ILE should be user friendly and the results of the simulation should be clearly reported and easy to understand.

If all the previous features are properly taken into account in designing an ILE, it will presumably become possible to advance double-loop learning, providing a safe place where mental models are challenged and a unique form of training is provided. In particular, all the above mentioned considerations seem to be particularly interesting when dealing with complex domains in which both tangible and intangible variables play a relevant role.

This said, although the literature on ILEs provides sufficient evidence of the relevance of these tools in learning oriented projects, further evidence is needed to determine their effectiveness when used for educational purposes in higher education settings and management education. These issues are discussed in the next section.

3. THE CASE STUDY AND THE LEARNING EXPERIMENT

In order to provide evidence of the effectiveness of ILEs in sustaining processes of individual learning, a simulation experiment was set.

The ILE was developed on the basis of a real case study related to a service-based business company. The group of participants was made up of 15 master (MBA) students with a background in management and economics. The simulation experiment was organized during a single day course in which the participants attended a brief seminar focused on the System Dynamics methodology. With

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324). In some cases, especially when dealing with professionals or operators, it could be also better to have interfaces reproducing as many features as possible of the original software used by their company. On the other hand, we could look at the situation from another point of view: when overused, graphs, data and information could inhibit user participation in the simulation and therefore hamper the learning process. Therefore, the ILE does not need to be completely realistic, or at least "adding realism for realism's sake is misguided" (Diehl 2000: 336).

[19] Isaacs, Senge (2000: 268) clarify this statement: "at the individual level, recent research and theory suggest that confronting management problems that are complex, nonroutine, and counterintuitive, such as CBLEs [Computer Based Learning Environments] pose, can create embarrassment and threat, and tend to trigger a set of self-fulfilling and self-sealing behaviors that diminish learning and the likelihood for change. Under these conditions, people may unwittingly defend prior positions, select information and arguments that confirm already established views instead of looking for reasons to change their views, attribute unreason and error to views that differ from their own, and often seek to «win», not learn".

[20] On the concept of *defensive routines* Argyris (1993: 286) explains that they are "policies and actions that prevent individuals, parts, or the whole organization from experiencing threat or embarrassment, and simultaneously prevent them from identifying and reducing the causes of the potential embarrassment or threat".

the project the participants were meant to achieve the following learning goals: learn systemic concepts; develop new ways of strategic thinking; challenge their mental models; improve their abilities to operate in complex domains.

It is to emphasise that all the students had previously took part in computer-based simulations (not System Dynamic ones) or had been engaged in confronting and solving traditionally structured business case studies. Further details on the ILE and on the experiment are presented below.

3.1. An overview of the case study and its learning goals

The case study used for the experiment plays out key features similar to many service-based business companies that are reliant on trained staff and on adopters.

The System Dynamics model embedded in the simulator portrays the business environment of a firm (called "Alpha") providing commercial services for its clients. When acquired, Alpha assists its clients with several supporting services through the call centre, answering queries, checking details, providing data and information, etc.

The ILE aims to make users learn about both generic and specific dynamics issues, as follows:

- business performance over time depends on the managed resources;
- it is fundamental to balance demand-side and supply-side resources;
- intangible (or "soft") variables can considerably affect the profitability of the firm and can influence the growth of tangible ("hard") resources (i.e. clients and employees);
- resources are won and lost (or increased and decreased) over time, but the rates at which such stocks vary are substantially different;
- there are several time delays active within the system and they are the reason of the oscillations experienced in many variables.

Further details on the model are provided in the following section through the presentation of the CLDs portraying Alpha's business environment. Subsequently, the main features of the ILE used in the project will be discussed.

3.2. The main CLDs of the simulation model

Alpha operates on a market made of potential customers. When acquired, those people become "adopters". In order to attract customers, Alpha manages four variables[21].

a) The *unit price* is a fundamental variable, since potential customers can easily compare the price applied by Alpha with that of other competitors. The discrepancy between such prices typically produces an attraction or a repulsion towards the services offered by Alpha (both for potential customers and, at a lower degree, for old adopters). Note that within the model potential adopters have been considered highly influenced by a favourable gap between Alpha's price and competitors' prices; consequently, even a small differential can considerably impact on the "acquisition rate". During the simulation, the competitors' average prices change over time, frequently in response to Alpha's decisions.

[21] Note that all the cause-effect relationships related to these variables are usually nonlinear ones.

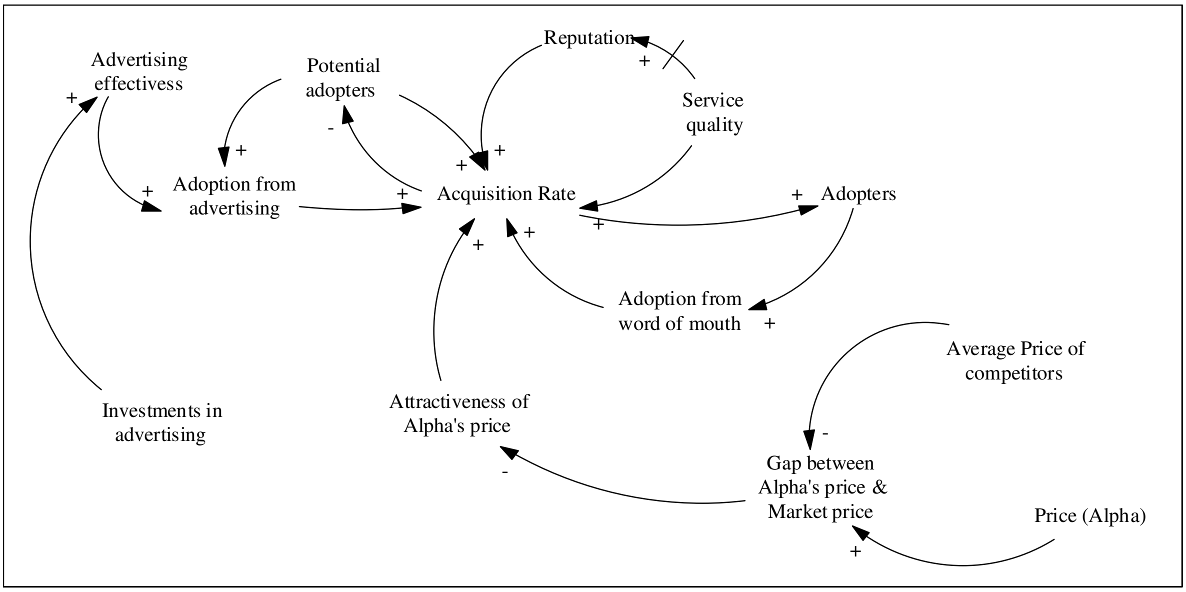
Adoption may also come from *word of mouth*, considered as social exposure and imitation. Adoption from word of mouth can be positive as well as negative.

b) Adoption may come from *advertising*, since commercials and ads on various media create awareness of the services offered by the firm, thus attracting potential clients[22].

c) Intangible resources as *reputation* can play a fundamental role. If Alpha owns a good reputation, it will benefit sales, attracting more potential customers. If the reputation is negative, Alpha will repulse potential customers and could also lose old adopters. Adopters could also abandon the company when the quality of the service delivered by Alpha is low, when there is poor service or when the price is too high.

All the above mentioned variables and their cause-effect relationships are shown in the following simplified causal loop diagram.

Figure 5 - *Simplified Causal Loop Diagram focused on clients and service*



This said, it seems relevant to stress how service quality and reputation are affected by other variables.

Service quality heavily depends on the comparison between staff capacity and workload required to assist customers. Much effort is required to deal with customers, in terms of setting up agreements, dealing with queries, checking details, answering telephone calls, providing information, and so on. Even when the clients decide to leave the firm, effort is required in order to process their requests and close contracts. In order to simplify, although each factor mentioned above is weighted in hours/person and has its own specific meaning, all of them has been reduced to one single index, named *workload*. This variable identifies the effort that should be provided by Alpha through its staff. In each moment the actual staff can provide a total amount of *capacity*, measured as the sum of productive hours that can be provided by the employees, weighting their experience and productivity[23]. Bad service quality

[22] It is to emphasise that the magnitude and the persuasiveness of the advertising is very seldom constant over long periods of time.

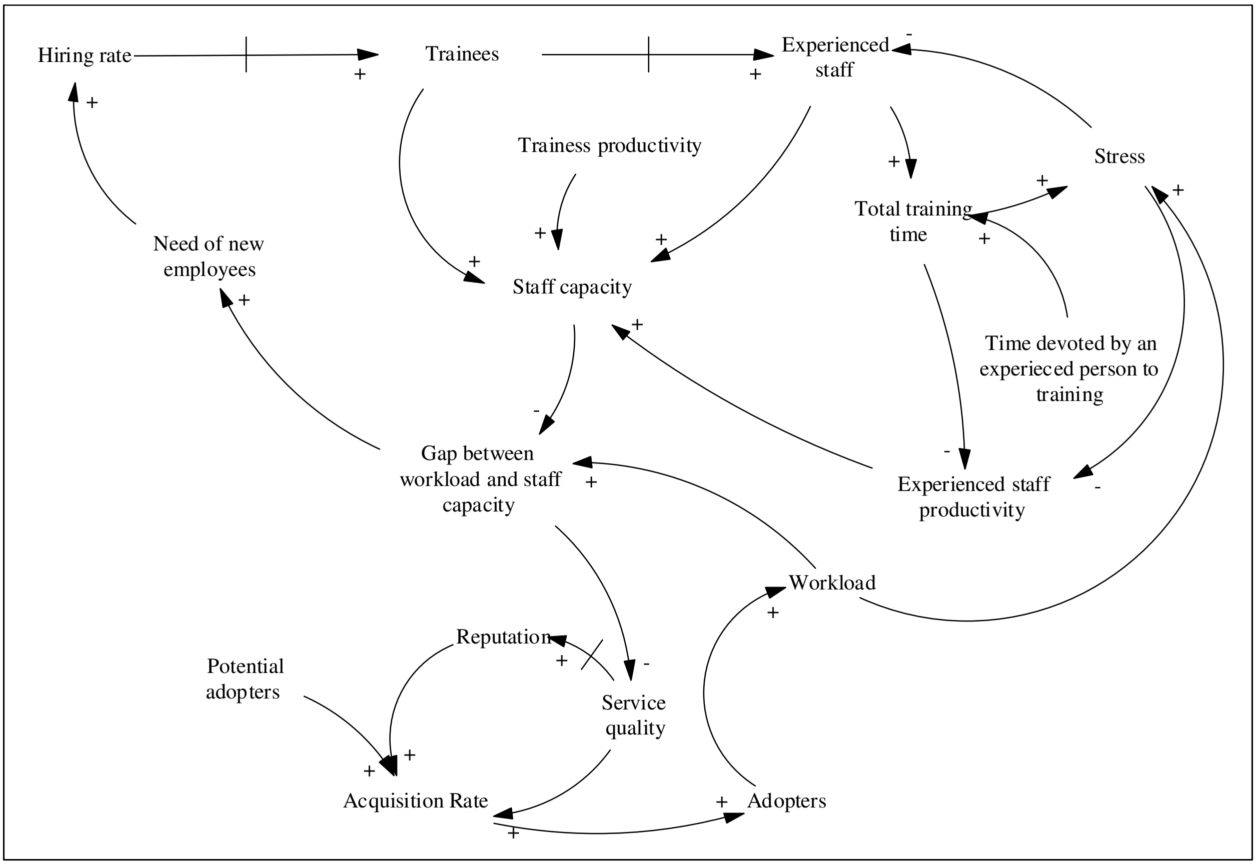
[23] The productivity of a senior is usually higher than the junior's and rookie's ones. However, in order to get trained, rookies required to be assisted by more experienced people, thus absorbing part of their time (and energy).

arises when there is a negative discrepancy between workload required and available capacity. This situation could be overcome asking the staff to work for longer periods but it cannot be sustained too long. In such a case, a “burnout effect” would occur and the employees’ productivity would quickly decrease.

Therefore, a main objective of the top decision-makers is to properly manage their staff, continuously balancing the workload with actual capacity and taking into account the delays that are active in the system (e.g. the time required to hire a new employee or the time required to train him/her in order to get a more experienced personnel). Note that trainees need time to acquire new skills and become experienced, while experienced employees are asked to put effort and time in training rookies. Subsequently, a delicate trade-off emerges: if on one hand this situation makes possible to increase new employees’ skills and productivity, on the other hand it reduces the available time and actual productivity of experienced people. In principle, rookies’ productivity was set at about 50% of the experienced employees’ productivity.

It comes out that the staff capacity is hard to manage and can be subjected to several and frequent oscillations, due to the above mentioned factors, influences and time delays. In particular, one of the goals of the users of the ILE must be to eliminate or reduce such oscillations. If this aim is not reached, the level of service quality will be low, the reputation will be negatively affected, and the company will not attract new customers or will even lose some adopters. In particular, note that the *reputation* is an intangible asset that is quickly lost, whilst it can be increased very slowly over long periods of time. All the above mentioned variables and their cause-effect relationships are shown in the following map.

Figure 6 - *Simplified Causal Loop Diagram focused on Alpha’s staff*



Expanding the analysis in order to consider Alpha’s operating results, we can highlight what follows.

Revenues basically come from the price multiplied by the number of operations made. Therefore, the number of adopters and their transactions with the company are key figures to control. Some other variables/situations need to be continuously verified, such as the spread between Alpha’s price and competitors’ prices and the effectiveness of key marketing elements (for example, word of mouth, advertising and reputation). Note that within the model it is assumed that Alpha does not receive income from any other sources, such as sponsorships or financial investments.

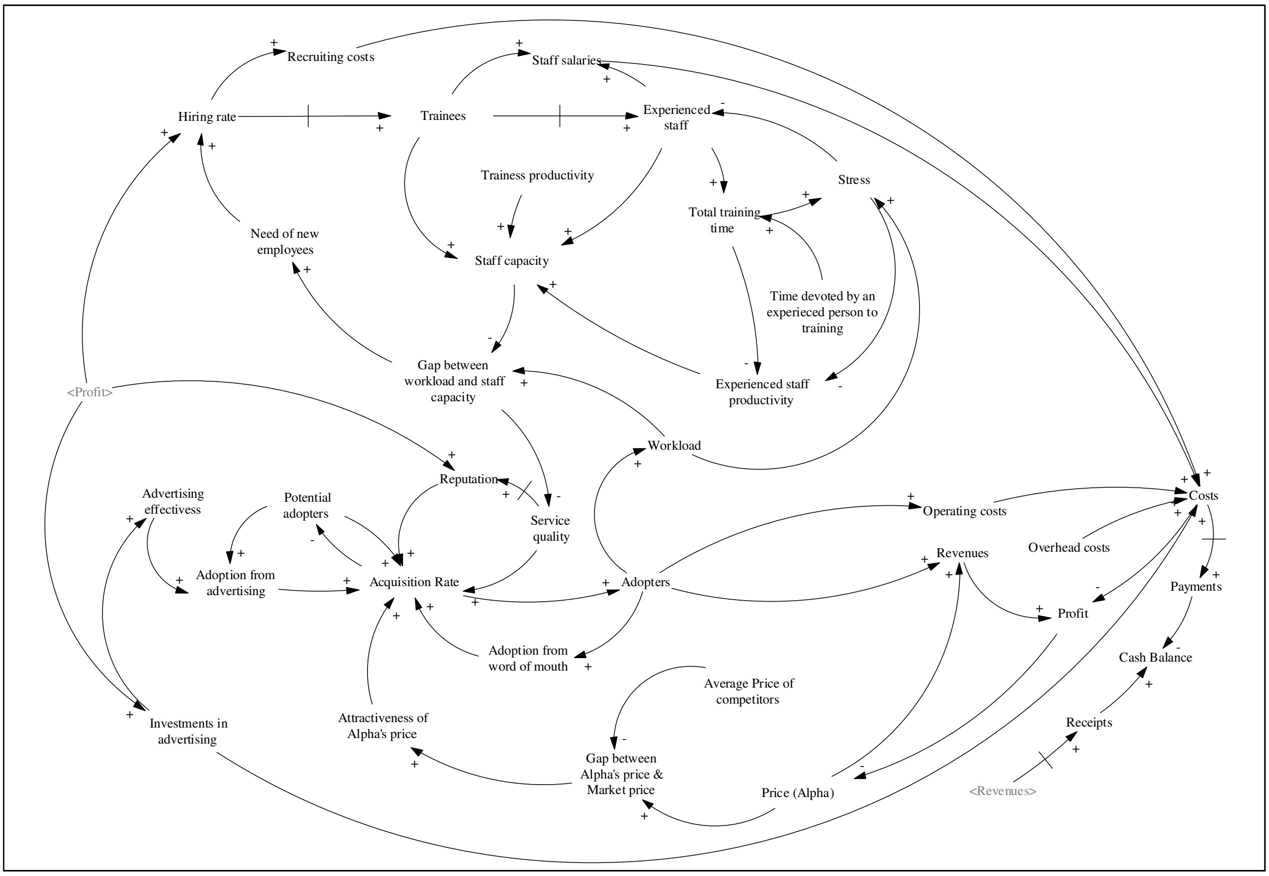
Costs are caused by a variety of situations and activities being performed by Alpha and its staff; most of them are related to salaries and operative costs, with particular relevance assumed by costs arising from customer activities. More in general, it is possible to divide costs into sub-categories as follows. First, Alpha has overhead costs. Second, costs come from the salaries given to the staff: trainees cost less than experienced workers. Third, customer service implies some costs as well, mainly to be considered as administrative ones. In addition, recruiting and training new workers is costly. Finally, even when a customer or an employee quits there are costs, related to the dismissal of such contracts and relationships.

Operating Profit (or *Loss*) emerges as the difference between revenues and costs, and *cash balance* is calculated subsequently.

As a final stage it is possible to identify the presence of some other feedback loops, taking into consideration the actual levels of the operating profit. For instance, positive results will lead to further increases in the effort devoted to specific policies, such as new investments in advertising or in recruiting or likely changes in the level of the price applied on the market. In addition, a huge operating profit will positively influence the reputation of the company, thus attracting new potential customers or investors. All these loops, if well identified and strengthened, can guarantee to sustain processes of growth.

All these relationships are portrayed in the map shown below.

Figure 7 - *Simplified Causal Loop Diagram reporting costs and revenues*



The previous maps were formalized into a quantified simulation model. In a later stage, the mathematical model was embedded in the ILE. Further details are presented in the next section.

3.3. The Interactive Learning Environment

The *Interactive Learning Environment* used in the project was developed in order to be easily understandable, clear in its functioning and objectives, and recognizable by the users in its basic features. The ILE was built using the software Powersim, linking the main formal model to an interface through which the players had the chance to experience some simulation scenarios.

The following table summarises the main features and learning key points of the ILE.

Table 1 - *Key features of the learning experiment*

1	Duration of the simulation session	Between 1,5 and 2 hours.
2	The lab setting	A modern laboratory was used for the experiment. Single computer positions for each player, an interactive electronic board for the conductor to explain the simulator, technical equipment (pens, pencils, calculators, etc.) were the basic features of the laboratory.
3	Time horizon of the simulation	The simulation had a 4 year time horizon. The decisions had to be taken monthly although a different time frame could have been set.
4	Decision inputs	Unit price. Hiring/Firing of service staff. Investment in marketing. Investment in training.
5	Objectives to achieve	High profitability over the given time horizon. Good cash balance over the given time horizon. Good balance between demand-side and supply-side resources over the given time horizon.
6	Performance outputs	Operating profit. Cash balance. Clients won and lost.
7	Exclusions	The players were not allowed to inspect the simulation model, only having the opportunity to analyse all the CLDs. The ILE did not include rivalry.
8	Teaching support materials	Transparencies. Users' Guide to the ILE. Teaching Note.

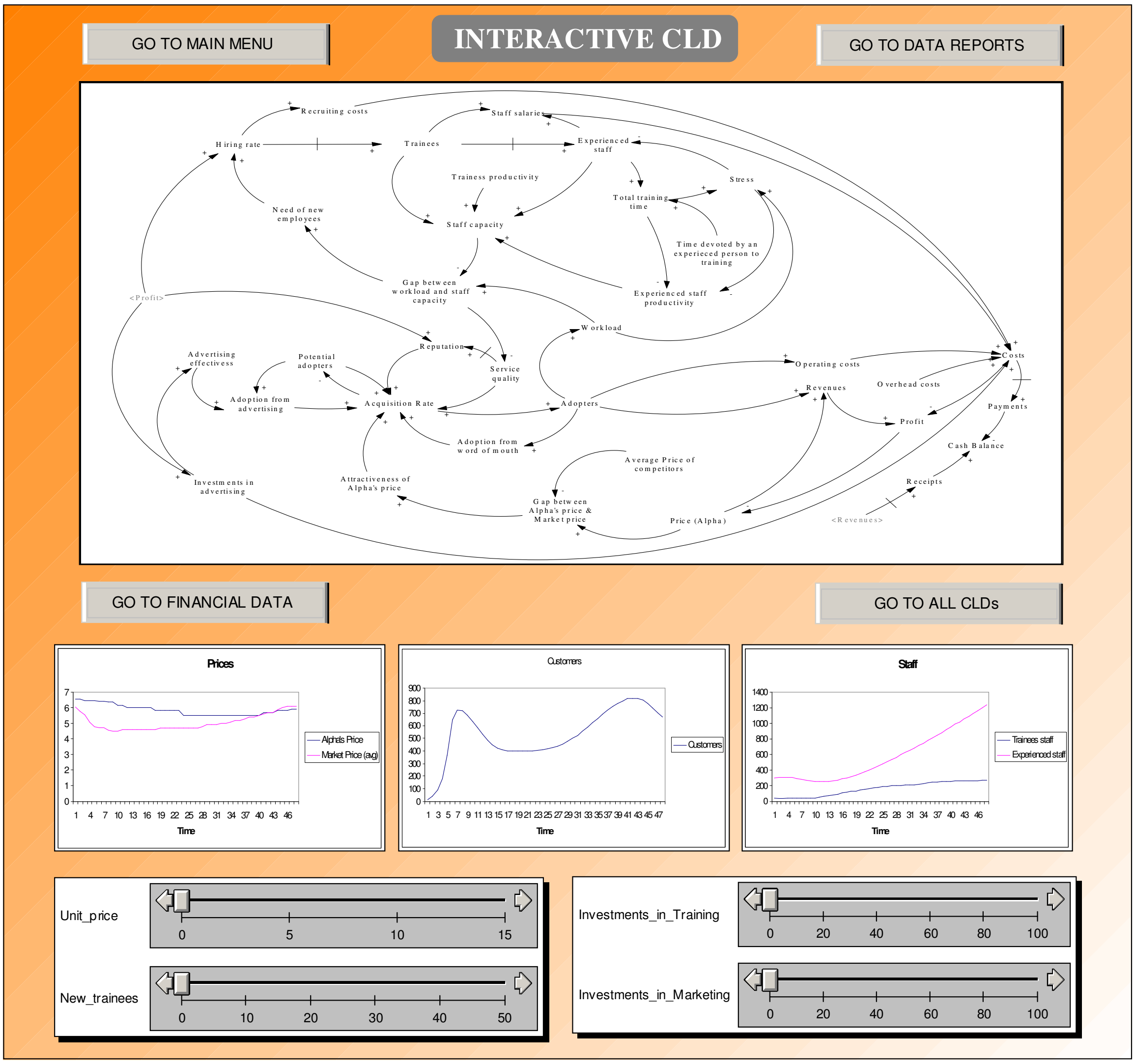
The interface of the ILE was made of several objects, as follows:

a) a control panel;
b) a simplified causal loop diagram portraying the main variables of the model and their causal interrelationships. This should have allowed the users to explore and understand cause and effects links and guarantee a medium level of "transparency" of the ILE. In addition, windows containing all the CLDs were accessible for the users;
c) graphs, tables and reports showing and containing details on the behaviour and actual values of the main variables of the model.

Players could gather additional information directly from the main menu of the ILE. Such information were related to the functioning of the simulator and to the scenarios that the users were called to face. To facilitate the interaction with the ILE, a specific *User's Guide* was created and handed out to the players. The author also drew up a *Teaching Note* for the facilitator, including all the needed information and details about the business scenarios and the handling of the simulator.

Some screenshots taken from the ILE are presented below.

Figure 8 - *Interactive CLD and graphical interface of the ILE*



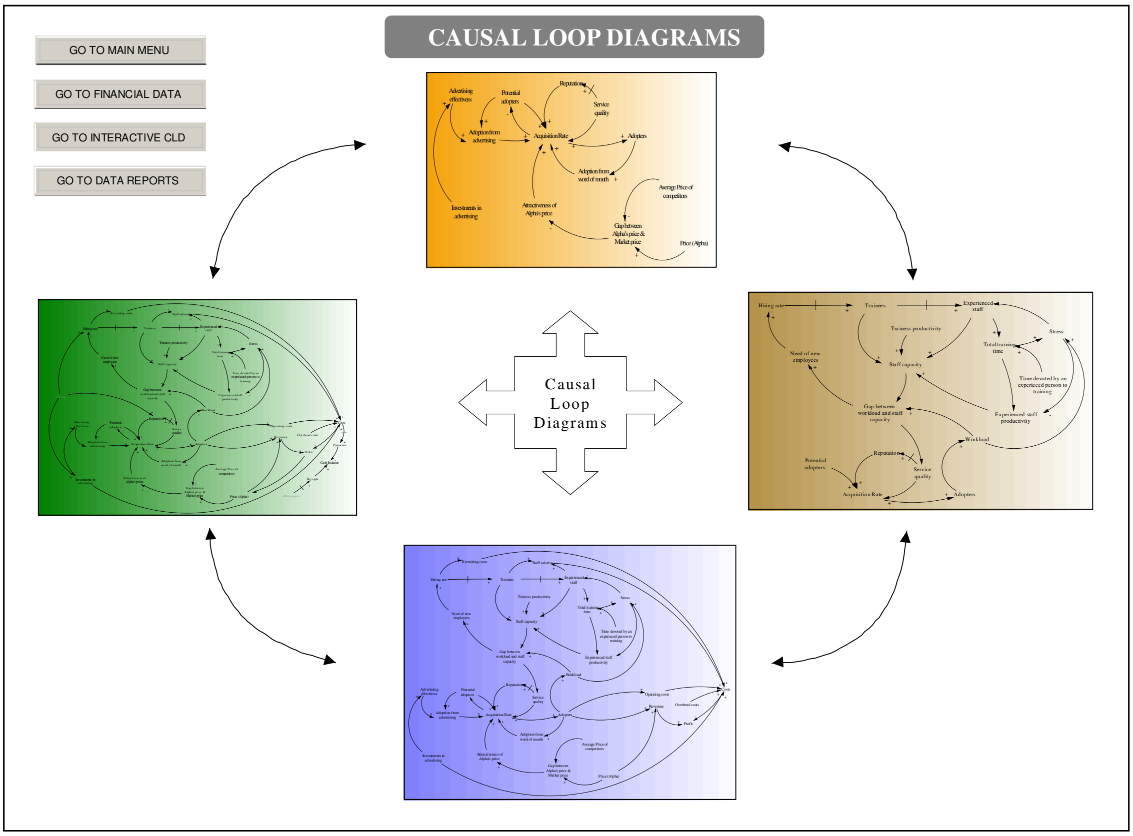
The figure shows the control panel and some of the graphs the players used to interact with the simulation model.

The users also had the opportunity to continuously check key results selecting among the available data reports. One example is shown below.

Figure 9 - *Screenshot related to the Data Reports*

Some other windows were created with the goal to represent a tutorial section of the simulator, from which the players could acquire further information about the business environment.

Figure 10 - *Screenshot related to the Causal Loop Diagrams representing Alpha's business environment*



3.4. The level of perceived knowledge

The ILE was used in a single session lasting between 1,5 and 2 hours. Previously, the learners had been given some explanations about causal loop diagrams and the main functionalities of the ILE during a 1 hour System Dynamics focused lecture.

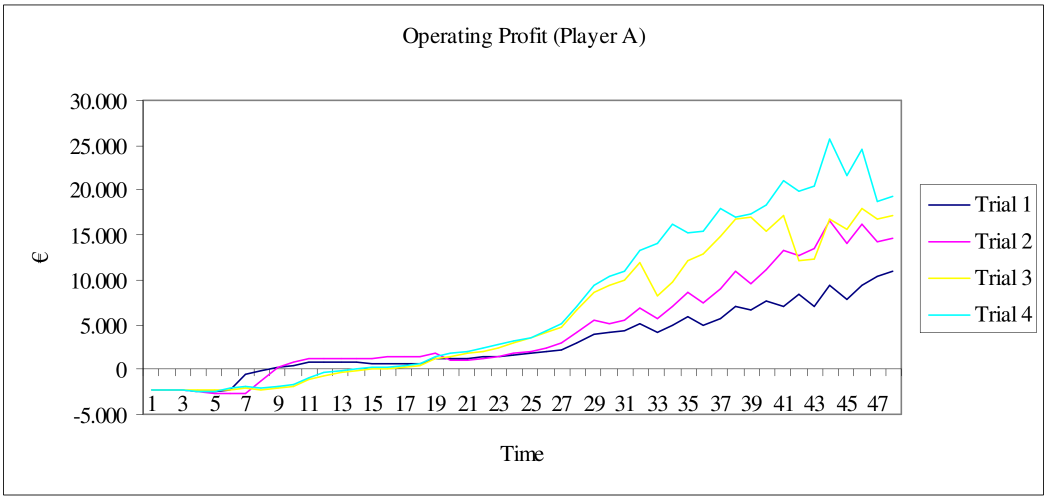
As a whole, the author feels that the meeting allowed to reach some of the aimed goals. In particular, the use of System Dynamics in the form of a comprehensive simulation model, the chance to analyse and understand the complex behavior of the business environment and the effects of some applied policies thanks to the ILE can be seen as the key elements that allowed to boost the process of learning during the experiment.

In order to better represent the level of knowledge gained by the users and the overall results of the whole simulation experiment, this section reports some results that were registered by the players and the outcomes of a questionnaire delivered to the participants. It is to stress that the players were assured of the anonymity of their simulations and feedback questionnaires: each player was randomly assigned a letter and the simulations were progressively labelled with numbers. For example, simulation "2B" refers to the second simulation run performed by the player "B". This setting ensured to make participants feel relaxed and not judged about their performances, at the same time allowing to check results and analyse individual performance improvements from run to run.

It is to mention that the participants were allowed to perform a maximum number of 4 simulations.

The performance of most of the players improved as the experiment went on, reporting better results in later simulation runs. Some examples of such improvements are shown below.

Figure 11 - *Performance of the Player A over the 4 simulation runs*



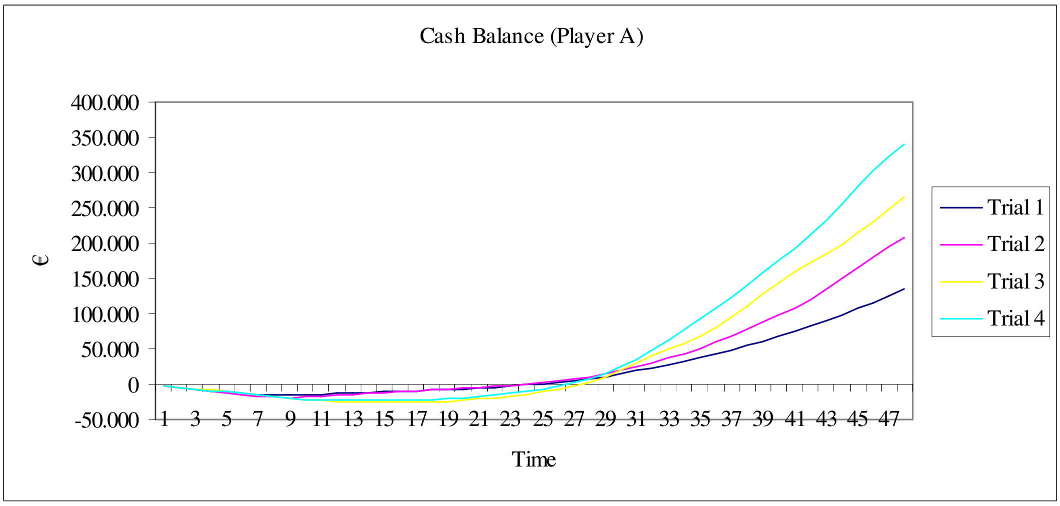
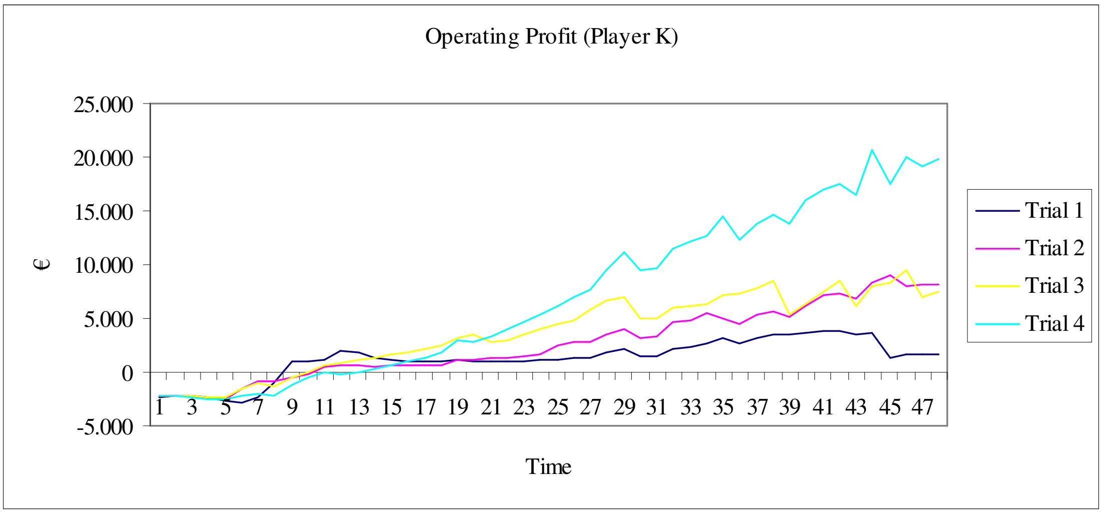
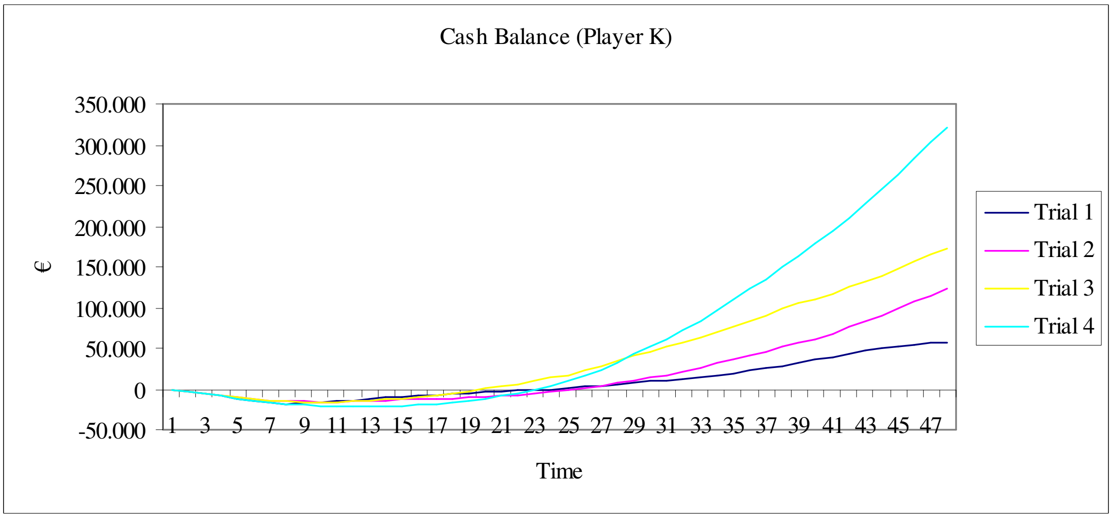


Figure 12 - *Performance of the Player K over the 4 simulation runs*





The improvements made by the players can be further analysed; in this regard, the tables shown below report the cumulative data related to operating profit and cash balance at the end of the four trials each player was allowed to perform. It is clear that in most of the cases considerable improvements were registered.

Table 2 - *Cumulative data related to the basic simulation scenario (Operating Profit)*

Operating Profit at the end of the simulation run				
	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*
Player A	144.468	220.484	280.286	359.349
Player B	65.717	44.395	71.279	65.075
Player C	32.615	94.205	114.430	141.662
Player D	-1.496	90.754	56.462	82.903
Player E	42.111	63.658	224.041	118.802
Player F	-595.391	4.396	45.208	24.427
Player G	17.864	34.178	128.858	271.964
Player H	-69.045	-10.237	-417.309	16.560
Player I	44.026	62.665	28.198	1.121
Player J	-35.367	-43.534	26.595	43.855
Player K	59.397	130.017	178.906	338.894
Player L	-86.957	23.065	61.238	112.432
Player M	-6.747	192.461	215.058	63.463
Player N	-124.458	31.274	89.952	32.792
Player O	161.167	285.314	316.044	330.137

Table 3 - *Cumulative data related to the basic simulation scenario (Cash Balance)*

Cash Balance at the end of the simulation run				
	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*
Player A	1.063.782	1.641.785	2.048.838	2.797.006
Player B	699.574	226.117	745.174	415.846
Player C	-1.255.812	1.075.634	878.071	1.284.058
Player D	-2.158.154	1.145.641	510.790	545.038
Player E	13.388	492.196	1.484.308	403.065
Player F	-8.742.602	-122.155	603.213	743
Player G	-1.811.691	-1.032.656	-133.488	965.832
Player H	-2.208.736	-740.617	-7.380.634	-1.688.221
Player I	203.609	767.689	-174.672	-978.258
Player J	-806.844	-1.337.616	434.058	715.373
Player K	432.457	930.658	1.982.425	3.088.986
Player L	-3.135.396	-349.160	383.092	1.179.049
Player M	-1.079.054	1.937.509	2.514.636	88.449
Player N	-5.738.779	-512.738	1.098.020	-61.421
Player O	1.507.733	3.050.306	2.179.325	3.560.162

In some cases, a few players did not show steady improvements. This was especially matched with erratic policies, characterised by frequent changes in the decisions taken by the participants.

To address and better understand if and how the ILE helped to improve the users' strategic thinking abilities, further investigation of their behaviour was needed. In particular, comments, suggestions and a cognitive feedback on participants' feelings and levels of satisfaction were collected through a "feedback questionnaire". Such results and information are shown in the table below.

Table 4 - *Some results from the "evaluation questionnaire"*

Question	*Answers*	*Frequency*
1. Did you find the ILE to be realistic?	a) Absolutely b) Moderately c) Not enough d) Not at all	5 9 1 -
2. Did you think that the dynamics shown by the ILE were enough realistic?	a) Absolutely b) Moderately c) Not enough d) Not at all	4 11 - -
3. Were you able to balance demand-side and supply-side resources?	a) Absolutely b) Moderately c) Not enough d) Not at all	1 9 5 -
4. Did you understand what kind of consequences are generated by time delays?	a) Absolutely b) Moderately c) Not enough d) Not at all	7 5 3 -
5. Which graphs/reports/information not available in the ILE would have been useful?	- More data on competitors' performance - Further details on time delays - Data showing competitors' customer satisfaction	
6. Which changes would you suggest for the ILE?	- The opportunity to take decisions on lead time. - A different time horizon for the simulation. - A higher complexity of the simulation, especially after some simulation runs.	
7. The simulator had two screens (Interactive CLD and Data Reports) you could select as your graphical interface. Which of them did you mostly use?	a) Interactive CLD screen b) Data Reports Screen c) Both of them	11 2 2
8. Which of the two screens did you find clearer and more useful?	a) Interactive CLD screen b) Data Reports Screen c) Both of them	6 5 4
9. From run to run, do you think that your level of confidence and awareness improved?	a) Absolutely b) Moderately c) Not enough d) Not at all	7 8 - -
10. Which are the most appreciated features of the ILE and of the experiment?	- A holistic view of the process. - The simulation sessions. - A moderately good training in managing a complex business environment. - The test of feasible policies. - A new way of facing business and managerial issues. - The realism of the dynamics portrayed by the simulator. - The graphical interface of the ILE. - The chance to discuss in a different way and with new tools a typical managerial case study.	

It is to note that after the experiment, half an hour was used to debrief the session. Topics related to the scenarios, the feelings of the players during the simulation, the strategies they chose and their expectations were discussed[24].

[24] Some of the questions that the facilitator asked to the players are the following ones: Did you feel comfortable handling the simulator? Did the business environment appear to be realistic? What kind of strategies did you apply? Did you use the strategies you would use during real working conditions? Have you done actions you normally wouldn't apply?

4. FINAL REMARKS

This paper dealt with specific methodologies and tools that could be effectively used in learning projects for HE students and managers. After summarising some relevant contributions on the issue of individual learning in complex domains, the work presented the key features and the principal outcomes of a computer based learning experiment.

The aims were to show that System Dynamics-based ILEs are particularly well suited for management education, being powerful tools able to improve users' strategic thinking capacities and to facilitate processes of individual learning.

This is particularly relevant in educational programs, such as MBAs, in which students have to develop system thinking and strategic thinking abilities related to complex and dynamic domains.

As said, very often in such courses the case study method is the most frequently teaching approach. If on one hand, this educational approach has clear strengths, on the other hand it also shows some weaknesses. It is our opinion that this situation opens up great opportunities for the use of System Dynamics based computer based learning laboratories and the experiment we reported was organized in this perspective.

In more details, the ILE was built to be oriented at the following learning goals for the participants involved in the project[25].

- *focus on conceptualization and abstraction*, providing a set of specific tools;
- *incentive users' investigation*, asking them to develop problem confronting and problem solving skills;
- *create opportunities for participants' reflection*, stimulating and improving their strategic thinking capacities, their understanding of complex structures and dynamics, and their abilities to solve structured and unstructured problems;
- *stimulate the development and implementation of new theories/skills*, also supporting the participants in developing a common language, learning new tools for system thinking, discussing operational objectives and strategies in an open form and without barriers, testing operating assumptions and experimenting new ideas.

Note that all the students involved in the experiment had been previously challenged with traditional case studies or simulation experiences (mainly with traditional Excel spreadsheets - not System Dynamics models). It is our opinion that this situation facilitated them to self-evaluate their degree of satisfaction regarding the use of the System Dynamics based ILE.

In order to provide evidence of the effectiveness of the ILE for the above mentioned learning goals, this work reported the main features and results of the experiment. The effectiveness of the ILE was demonstrated both by the positive performance of the players and by the positive answers collected via

[25] As Isaacs, Senge (2000: 270) point out, the central purpose of ILEs "is to provide decision makers with new opportunities for learning through conceptualization, experimentation and reflection that are not easily achieved in everyday management activities". Therefore, ILEs are primarily used for educational purposes although, as Davidsen (2000a: 170) argues, they may differ "widely in purpose, use, domain, scope, quality, and implementation. We distinguish two kinds of purposes for which we use ILEs: learning and research validation". For further details on these topics also see: Graham *et al.* (2000: 235) and Bakken *et al.* (2000: 247); Davidsen (2000b: 302). However, ILEs have their own limits as well. For further details about the limits to learning in computer-based environments see Spector, Davidsen (1998) and Isaacs, Senge (2000).

a “feedback questionnaire” handed out to the participants. In particular, the performance of most of the players considerably improved during the experiment and from run to run.

From the feedback questionnaires also emerged positive comments. We stress again that, in principle, an ILE proves its validity and usefulness when able to enrich managers’ and users’ mental models, make their ideas clear and explicit, challenge their own beliefs, conduct many cycles of action and reflection. In this regard the participants clearly emphasised the strengths of this method and the benefits they recognised using the ILE.

In sum, we believe that the use of System Dynamics in the form of a quantitative simulation model (combined with the analysis of some qualitative maps - CLDs), the chance to experience the behavior of the simulation model thanks to an ILE, and the procedures followed in order to measure the level of perceived knowledge gained by the players, can be regarded as the most successful features of the overall project.

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