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Construction and Evaluation of Scenarios as a Learning Strategy through Modelling-Simulation

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Abstract

From a systemic perspective and in the context of an increasing generalization in the use of new technologies and the change in the educational paradigm -which emphasizes guided and autonomous learning-, the learning strategy should be routed to join logical reasoning and instrumental skills (software). The inclusion of new computing and communication resources to the learning process turns them into teaching tools, which makes it possible to organize the teaching and learning process in a different way. The design of these new scenarios of study has important implications to the way information is processed, to the different levels of learning (descriptive, explanatory or analytical ones) and to the way knowledge is acquired and evaluated. In addition, that design takes into account the greater student-content, student-student and student-teacher interactivities, always emphasizing guided independent learning. Thus, the construction, analysis and evaluation of scenarios through models and simulation are the strategy that best suits the current learning style followed by students.

Keywords

New technologies, paradigm, logical reasoning, instrumental skills, scenarios, interactivity, modelling and simulation

1. Introduction

In a context of growing demand for software that can help make sense of increasingly larger and more complex sets of data, where Internet connectivity and other communication media also grow simultaneously, allowing us to interact and learn from the massive data flow, the student´s ways of thinking and the teaching approaches are altered and tend to change for more dynamic structures. That is, the ways to extend background of new knowledge and to live with the data change, as well as the ways to support new technologies to overcome the old forms of social interaction and business.

The idea is to make the students learn how to scientifically approach the process of modelling and evaluation of scenarios through simulation, in addition to developing intelligent views to communicate their results significantly. From this perspective, modelling and simulation have a dual purpose. First, guided learning of a phenomenon or situation through the reformulation of the mental model. Second, autonomous learning as part of the natural process of change in mental images in interaction with the phenomenon under study. The purpose is to use the experience that students have outside the classroom, where they solve real problems of complex and ambiguous nature using cognitive and intuitive strategies and tools (Krajcik, J. et al., 2000). Hence, the task of the teacher is to show the student how to think and calculate, relying on the potential interactivity of new technologies interfaces as tools for amplification of logical reasoning, in order to lessen the cognitive burden required for the studies (Bouciguez and Abásolo, 2010).

2. Contextualization of the relationship between new technologies and learning

The huge development of digital environments and media has driven the proliferation of devices used by people to consume content at home, at work, at school and in the activities of every day. Not long ago students and workers relied solely on their desktop computer for their online connection. Now, an increasing number of people are likely to access a wide variety of digital content through a variety of devices on a daily basis. With laptops, smartphones, tablets and other connected devices, people have become digital omnivores; not only by the media they consume, but also in the way they consume it.

In this world where continuous connectivity between people, organizations, and between people and organizations prevail, the challenge is to ensure that student is able to develop its common sense[1] and understand the relationships that exist between objects, not from their absolute position in space, but from their simultaneous interactions at a given time and space position. This space-time simultaneity has created an environment characterized by the availability of huge amounts of data, large number of variables and a wide variety of interrelationships that have led to the development of new knowledge and the performance of many complex tasks not achievable until a few decades ago.

From a scientific perspective, the change has meant, first, the review and reflection on the knowledge acquired, the experiences and the operational skills, in order to implement increasingly complex operations. Second, it has led to the diversification of technological designs aimed at creating platforms and digital media for autonomous guided learning, which has changed the way of understanding the functioning of complex actual systems (physics, chemistry, biology, economics, psychology, etc.).

3. Current discussion and contribution to the state of the art

The literature on ways to investigate current and future reality (prospective) shows that autonomous and self-guided learning has evolved from the development of quantitative-and-qualitative estimation and forecasting techniques towards handling situations involving uncertainty and multiple options, in addition to the various forms of data and information processing and their interpretation (Medina, 2000; Mujica, 1998; Shoemaker, 1995; Bertrand de Jouvenel, 1967; Kahn, 1967; Gaston, 1957).

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[1] *Common sense* is a representation of past experiences, and situations previously encountered and resolved.

While this inquiry process has been developed in the context of a systemic view of the economy and society, the dominant emphasis has been on solving the problems associated with converting the models into machine language, and not on the design and construction of scenarios which are the basic elements of modelling and the subsequent simulation (Guilhou & Lagadec, 2002; Prigogyne, 1977). Particularly when a wide variety of multimedia devices exist in the market, offering the students opportunities to do things that would be otherwise impossible in the "traditional classroom" environments (Schneps, 2014, Harvard College Observatory).

From this perspective, the contribution of this paper is to understand the process of inquiry as a way of articulating the logical and instrumental reasoning, based on an iterative approach: student-teacher, student-content, student-student and student-computer, in order to improve the management of changes in students learning strategies without compromising scientific rigor in capturing specific ways to use the functionality of the system as well as capturing the different application scenarios. In order words, it emphasizes aspects of model designing and the use of the multimedia simulation tools already available.

4. Change in the educational paradigm

The premise accepted as the basis of education has gone from lecture based learning to another focused on the learner, grounded on the acquisition of vertical and transversal skills that strengthen the student´s ability of independent and guided learning. In this paradigm change, the idea is to abandon the search for absolute laws and theories in favour of finding approximate laws and theories, as truths are only in relation to the structure of dominant knowledge and methodology in use at that time, thus leaving open the possibility of being overcome in the future (Popper, 1979; Lakatos, 1978).

Learning centred on the "learner" and grounded in the idea of generating knowledge as approximations, by articulating the logical reasoning and instrumental skills (software), including an assessment aimed at determining how to apply theoretical concepts and how to use operational and technological techniques, endorses systemic thinking. The fact that all advance in knowledge involves a reorganization of cognitive structures as a result of tests applied to statements taken as true so far, means the delimitation of its content, application and generalization (Lakatos, 1978). This learning path enables understanding and consolidation of concepts and methods which are part of laws or theories used in the study of phenomena, and allows the subsequent model enactment (simulation) to explain the underlying feedback on learning and to interact with the various possible scenarios of reality.

Hence the theoretical thinking nestled along this discussion is systemic, and its enactment through simulation is understood as a paradigm of thought, made evident through certain structure of own language or conventions (Andrade et al., 2001). The use of simulation as part of the learning process is due to the fact that humans better perceive the changes in situations represented in either temporal or spatial motion. So, if a student cannot decipher the exact mathematical formulas included in the models, then observing the relationship diagram and/or graphic, e.g. about climate, in motion, could enable him to predict certain events much faster than with other types of analysis[2] .

4.1. Systemic Perspective on Learning

The difficulties that are generated in the process of knowledge acquisition (learning) are part of complex cognitive networks and of the "appropriation" of knowledge[3] , which not only hinder, but also feedback, the learning process. The obstacles become evident in wrong answers due to the failed attempt to adapt knowledge, previously acquired, to new situations (Sacas, 1997, Werner et at, 1995), while feedback becomes evident in how the

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[2] Today, models of weather forecasts tend to seek a balance between graphics of rain clouds and moving snow with maps which use numerical coordinates and numerical time tables of events (tables of coordinates of clouds and rain).

[3] Appropriating something and inserting it into the personal background. This is what significant learning does, producing useful long-life knowledge, in addition to transferring it to other fields of knowledge, to change reality learning creatively.

student learns and appropriates knowledge, following the scheme: observation-intuition-reasoning-interpretation-observation.

In this context, a concept that addresses the parts and the connections between the parts, to study the whole, will help to understand the complexity of the diversity of combinations of relations of one part to the other. It will also be useful to overcome obstacles and conceptual confusions that lead to stagnation and decline, by explicitly considering this feedback present in the acquisition of scientific knowledge.

Today, training in the development of conceptual and formal models and the use of digital simulators, are only included in Masters and PhD programs but are not in the curricula of university degrees. This situation has not been substantially modified so far, probably because of the level of knowledge required for its implementation in bachelor's degrees, particularly those abilities and skills related to formal modelling and coding (or machine language) so that they can be interpreted by a computer (Evans, and Fashan, 1993).

Advances in the development of "friendly" simulation programs based on the user-computer-user interaction, open the door for the inclusion of methodological developments in the modelling of systems and/or scenarios, in the curricula of university degrees. This fact is reinforced by the wide range of simulation tools for academic and business fields, such as Vensim, iThink/Stella, AnayLogic, Evolution, PowerSim, Smile, Arena, ProModel, Siman, SimulAr, among others.

4.2. New technology resources as teaching tools

A To some extent new technologies are part of the daily activities of students and gradually install new practices and learning styles. In a context of continuous reduction in the costs of data collection and the generalization of digital storage, the relevance of the introduction of these new computing and communication resources lies in the actions or practices that are enabled by this technology itself, and the stimulus to organize the teaching and learning process in a different way, by using technology as a teaching tool.

The growth of the "information technology" has created new types of data and data structures, which are faced by students in their personal, academic and social life, including techniques to collect their personal information, as well as their social or cultural group data, with the goal of monitoring the day-to-day life of these individuals or groups (Facebook, Twitter, LinkedIn, etc.). This makes today's students live with the data and have a direct, first-hand experience.

This experience also covers the use of search engines like Google, Yahoo, MSN, Gmail, Bing, Rtbot, DuckDuckGo, Yacy, Hakia, Open Directory Project (ODP), Accoona, Yandex, Gennio, Ask Jeeves, ApocalX, Yippy, Ixquick, Kartoo, Carrot, etc, technical (graphical, statistical, simulation, etc.) software, digital databases (Big data, data mining, etc.), tools that could be used for academic learning and leisure; for example, in the preparation of the bachelor or master degree thesis (including topics like creating online companies, customer management, video game design, web positioning, dynamic marketing, iPad as a learning tool, etc.) .

While the conversion of these resources in teaching tools is neither immediate nor automatic, its academic use is untapped, for example the possibility of studying the events with the whole population and not just a sample. The digital environment created by the IT opens the real possibility of restructuring classroom teaching and the development of autonomous and self-guided learning styles. For example, using the Internet to browse for data, bibliographical sources, procedures, estimates or opinions is a step towards this goal. However, the main activity in this environment is still leisure related.

5. How to organize the teaching-learning process differently

Our proposal to organize teaching and learning in a different way is based on significant changes in the way the student processes data and information to turn it into knowledge. Thus, if the data filing can be accomplished in multiple ways, then the data only express one part of reality, and they do not express reality itself. The information in turn can be understood as the meaning that the data acquires as a result of an intervention, i.e., a conscious and intentional action. The knowledge resulting from this interaction can be seen as an active and interactive understanding of reality, an activity that is not devoid of an axiological characterization and which has got historical and social dimensions.

One implication of this metamorphosis is the outlining of the multidimensional interdependence relationships based on the spatial and temporal information feedback, making use of a calibrated modelling process at the different levels of learning (descriptive, explanatory and analytical). This transformation involves making explicit the connections of any type of intervention (by students or teachers) on databases and selected data sets, with the goal of getting information and then achieving new knowledge. In fact, accessing the former (data) is a necessary but not sufficient condition for the second (information), and accessing the second is a necessary, but not sufficient, condition for the third (knowledge), and so on, until an equilibrium where knowledge is consolidated and incorporated into the background of the students is reached.

The pedagogical strength of this approach comes from the multi-perspective connections that students develop about the changes in the events or phenomena of interest. These multiple interconnections are specified in the modelling process, and can be understood as the different ways of seeing reality. For example, when watching a video, at standard speed, students can perceive the spatial-temporal nature of the changes in their global context and identify the complexity of the relationships between the changes produced as well as the limitations to carry out the measurements. In contrast, when watching it at slower pace they perceive other aspects of the problem that are not visible with the previous method.

The scenario philosophy tells us that the investigation of the nature and the implications of the different perspectives or alternatives considered lets us visualize and identify the evolution of "future" behaviour of the phenomenon under study, considering different working hypothesis. Thus, for example, the technique of scenario modelling can be a useful tool to assess the management and application of concepts in defining variables, interrelationships, conceptual and mathematical formalization of behavioural relationships, as well as to explain the nature of the underlying feedback process, which affects the way knowledge is accumulated and the way prior knowledge is modified. It is also a good way to motivate overcoming superficiality and the prevailing relativism (the everything-is-allowed attitude) as it requires theoretical reflection, understanding of the dynamics of the problem and accuracy in the application of formalization, instrumental and operational techniques.

5.1. The pedagogical role of modelling

Th The pedagogical role of modelling refers to the competence that the student has to perform autonomously and conscious, throughout the modelling process in a given context (Blomhøj, 2004). This is possible by linking the modelling process to the teaching-learning process, suggesting problems about different situations, for example, situations that are written literally, so that the student must read, analyse, interpret and model the overall situation in order to define a particular solution. Logically, if a student faces a problem, in most cases he must go over the theory and investigate the nature of the problem in order to have conceptual elements that allow him to approach and begin the process of modelling. For example, the Functions of Real Variables can be used as models of natural phenomena and problematic situations related to economics or statistics. In particular, Exponential and Logarithmic Functions can be used, among many applications, to describe population growth, radioactive decay, compound interest or logarithmic adjustments and scales.

Pedagogical modelization is a cross competence in almost all disciplines, and its goal is the application of this method to the analysis of certain problem-situations, where a direct solution is not possible but it is necessary to propose alternative solutions (scenarios), based on the formulation of working hypotheses. The system modelling process begins by identifying the relationships and interrelationships between elements of the system under study, and then it continues with the construction of the conceptual model for the behaviour relationships, which is nothing but an equivalent and logical representation of the real system, and as such constitutes a simplified abstraction of it. Next it is translated into a model suitable for implementation on a computer, thus promoting the understanding of the underlying concepts, the control of variables, the formulation of conjectures and testing the student´s mental models. For example, Stewart (2007) proposed modelization as a teaching and learning strategy in the field of mathematics to study calculus and differential equations.

5.2. The pedagogical role of simulation

The pedagogical role of simulation has much in common with experimentation and/or "direct" experience with the problem under study; its value is that it allows assessing events which are often impossible or difficult to study in a laboratory, as in happens in many areas of knowledge, as they facilitate the dynamic representation of the system operation, and allows the visualization of the problem in its evolution and interaction.

In academia, the interactive power of interface simulation allows a high level of interaction of students and instructors with the phenomena of interest, many of them with specific purposes associated with certain specific characteristics, such as interactive graphics environments and instructions for studying different types of scenarios (waiting lines, manufacturing processes, etc.). Therefore, the simulations enable the student to extend and expand his cognitive process, helping him to address complex and ambiguous problems, give meaning to scientific knowledge, and to diversify his instrumental skills, especially those related to scientific and technological codes management.

6. Construction, analysis and assessment of scenarios

The purpose of the study of scenarios is not to predict future events, but to study, understand and create alternatives today, leading to achieve the desired objectives and minimize the effect of the unwanted ones. Hence, the claim of the modeller and the simulator is not to forecast, but to consider the many changing dynamics of chaotic emerging events, and to define and delimit the possible scenarios that are derived from them. In a complex world these characteristics imply that it is impossible to predict all possible states. In response, current scientific developments suggest to explore the multiple scenarios and possible trajectories, based on a set of assumptions that affect the scenarios.

During the study and scientific learning of the different dimensions of the real world, it is usually not possible to find an analytical solution, so we turn to modelling and simulation as an alternative. Modelization involves the formulation of conjectures or working hypotheses that determine the behavioural relationships and the interrelationships between system elements (logical, functional, and/or mathematical relationships) that take the form of a conceptual and/or formal model, although given the complexity of relationships in the real world, the "future" can only be explored.

Methodologies for scenario creation and simulation try to explore possible alternatives.

Although it is possible to compare certain aspects of the physical system with its formal or mathematical description, it will never be possible to establish an exact connection between them. The idealization of reality assumes that the observed data were generated according to certain logical and well-defined mathematical rules. From this perspective, the construction of "scenarios" is a conceptualization process, going from the possible scenarios, to the likely ones and then to the desired ones. The possible scenarios are all the conceivable ones, the likely scenarios are those with some chance of occurrence and the desired ones will be all those scenarios that can occur and are preferred over the others. Therefore, the acceptance of a simulated model should be guided by its "usefulness" instead of its "veracity", both in its formal and its fictional description.

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7. The process of modelization and modelling creation

Our proposal aims to improve teaching and ensure that students acquire and manage certain concepts, develop procedural and instrumental skills, and above all not to perform activities of just copying the teacher’s instructions and explanations but to think, question, deduce and infer from them. The design of a learning environment based on conceptual and formal (mathematical) system modelling activities is the best way to improve the objectives pursued and from that to establish scenarios under certain hypotheses that will be analysed and evaluated through simulation.

The procedure will be to follow the models or the different activities suggested by the teacher, with his help. Then such assistance will be gradually reduced, guiding students to the systematic use of the content used by the teacher to ensure a shift of the interpersonal and collective competences towards the intrapersonal ones, so that the student is able to use them independently. The way to achieve this transfer includes 5 phases (Law and Kelton, 1999. Chap. 5).

Phase 1. Problem identification

Phase 2. Dynamic hypothesis formulation

Phase 3. Model Formulation

Phase 4. Validation of the model

Phase 5. Scenario Building

Phase 6. Design, development and assessment of policies

Phase 1. *Problem identification*. The early identification of critical factors in the process allows the definition of the relevant variables, parameters, and internal and external constants. In this process, among other things, dynamic behaviour, the agents involved in the system, feedback processes, and especially the behaviour of the environment are discussed (Gomez and Dyner, nd). For example, in the normal foresight processes, after identifying the relevant factors, we proceed to weigh these factors considering their importance. The idea is that it is the model itself which determines which factors have the greatest impact.

Phase 2. ***Dynamic hypothesis formulation***. A dynamic hypothesis or conjecture is understood as the foundation on which the behaviour of a variable rests, sustained on a reasoning based on the feedback structure of the model that contains it, and on the model simulation using the appropriate software (Steels et al, 2011). There are two possible modes for building dynamic hypotheses: estimative and explanatory. In the estimative mode a possible behaviour of the variable of interest arises from the structure of the model and a first dynamic hypothesis is proposed; then the behaviour proposed and the initial hypotheses formulated will be tested using the simulator. In the explanatory mode we start from an already known behaviour of the variable of interest and through structural analysis an initial hypothesis is proposed which is then tested and adjusted with simulation experiments. Once this dynamic hypothesis is created, it is used for the definition of policies (design of a comprehensive and consistent set of structural changes) to promote the desired behaviour on the variable of interest.

Phase 3. ***Model Formulation***. The development and elaboration of a model is the starting point for really testing the student´s or the teacher´s understanding of the problem. Models promote system understanding ("insights") to infer and not necessarily calculate its behaviour and finally intervene on it. In this process, each variable must correspond to a concept in the real world and each behavioural equation must have dimensional consistency. In more advanced applications, the use of models that describe the relationships between the variables of the system in terms of mathematical expressions - as differential equations or finite difference equations- in more detail will be necessary. These models can be characterized on the basis of certain features (continuous or discrete in time, with centred or distributed parameters, deterministic or random, linear or nonlinear, etc.).

The possibility of practical modelling testing using computers and construction and simulation software allows the student to continuously acquire conceptual and procedural knowledge. Among the activities developed in the modelling process we can find: the design of conceptual and numerical schemes, scenarios simulation and sensitivity analysis, among others. (Hestenes, 1987). Modelization software has a relevant role in developing the student skills and abilities in the application of logical reasoning, in the conceptual understanding of the problem and in assembling relations and interrelations in a model (Andaloro et al, 1991). Simulation programs allow us to understand the dynamics of the interventions on the problem by creating different scenarios associated to the change of the working hypothesis. This form of computer supported learning is now developing in university education (De Jong et al., 1992), providing a means to increase motivation and the range of topics and experiences that the student receives.

Generally, models and reality are related through two basic processes: abstraction and interpretation. Hence, the first step in the modelling process is the abstraction of reality or situation under study. For that purpose it will be necessary to establish certain hypothesis, define variables, parameters and behavioural equations and finally develop appropriate mathematical operations to solve the problem. The second step will be to simplify the mathematical tools used. The results derived from the model should allow interventions on the real world. The next step will be to collect data of the effects in the model and compare them to the effects of interventions in the real world; if they don´t match, the data collected will be useful to modify the hypothesis; on the contrary, if the consequences of the intervention match those of the model, then the assumptions made are valid and so are the variables defined and the pre-set parameters.

Phase 4. ***Validation of the model***. The validation process consists of checking that the model meets the design requirements for which it was developed. It seeks to assess whether the model behaves according to the parameters set in its design. At this stage the differences between the operation of the model and the real system are also assessed by simulation. The most common ways to validate a model are:

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1. The expert opinion.
2. The accuracy in the reproduction of the historical data.
3. The quality of the scenarios for the analysis.
4. Model and simulation failure check

This process of validation of the model runs on both the time domain and the spatial domain, or on both of them, including its assessment in extreme conditions, expressed as values of the scenario variables that will never be seen in the real world, for example, a null GDP, zero inflation, 100% birth or mortality rates, among others. Under such conditions, the response of the model should not violate the laws (whether physical, economic, logical, etc.) that contextualize the problem. And it should be checked whether there is a relation between the variables that make up the model, the correspondence with reality of the concepts used in the model and its spatial and dimensional consistency.

The other side of the validation process is studying sensitivity, which consists of determining the magnitude or degree of impact of changes in a domain or parameter on the relevant variables of the model. For example, we can use methods based on the linearization of variables to assess the sensitivity of these to changes in the cycles domain (Forrester, 2011). That sensitivity is calculated from the coefficients eigenvalues, representing each variable as a linear combination of the others. These values express the rate of change in a variable as a result of changes in the range where model cycles are valid.

Phase 5. *Scenario Building*. A scenario is a method to guide the explanation of a system’s behaviour from the dynamics of its underlying structure. In the words of Kahn (1967), they are descriptions of the possible "future", in which attention is paid to the causal processes and the decision points. According to Kahn, the scenarios correspond to two fundamental questions: How does a hypothetical situation in the "future" happen, step by step? And what alternatives exist for the different actors at the decision moment to prevent, divert or facilitate the process? A scenario can thus be defined as a set consisting of the description of a "future" situation and the trajectory of events which allow the situation to go from home to the "future" situation.

The scenarios represent the symbiosis of modelization and simulation, built to test hypotheses or develop decisions structures, in different environments, so that when the decision maker faces the materialization of one of those "futures", he will be able to make decisions or actions to overcome the problem under study. It is a testing ground for ideas and a stimulus for new developments. Therefore it is useful to organize guided learning, as a scenario can tell the story of the possible interventions and its consequences.

This process of scenarios building has its corollary in simulation. Simulation helps to investigate sets of working hypothesis, using models or "observations", which show the nature of the changes in the structure or in the scenarios parameters. Through experimentation it seeks to identify changes in the pattern of the variables of interest behaviour to assess whether these feedback structures are dominant or not at some specific stage. The results of the experiments allow obtaining information that supports, contradicts or complements the initial dynamic hypothesis proposed.

Phase 6. Design, development and assessment of policies. In the first place, the policymaking process involves the reclassification of exogenous variables, into scenario variables, i.e. variables which cannot be modified by the decision maker (student, teacher, client, etc.) and which contextualize the environment in which the system is immersed. And in the second place, despite being exogenous to the model, into decision variables which are subject to change by the user.

Experiments can be directed towards the development of tests, such as the deactivation of a cycle or a parameter modification. To deactivate a cycle one must proceed to temporarily override one of the existing causal relationships, in order to temporarily disable its feedback process and to examine its effect on the behaviour of the variable of

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interest. Attention should be paid to prevent this link to be part of another feedback structure to only assess the dominance of the cycle to be deactivated. Changing parameters and auxiliary variables directly affects the behaviour cycles; thus the idea is to assess its dominance in certain stages of the variable of interest.

8. Limitations of this type of studies and contribution to the learning practice

Obviously, the formulation of any proposal of autonomous and guided learning has certain limitations arising from the fact that the design of a model involves a structure with certain restrictions:

- Scenarios with missing information
- Scenarios with misinformation
- Scenarios with ambiguities
- Scenarios with contradictions
- Fully or partially overlapping scenarios

These limitations are a consequence of the difficulties in defining the scenarios, visualizing the relationships and inter-relationships directly, identifying the situations that have arisen and finding the points of division and articulation of relationships, including delays in the impact of actions and the positive and negative feedback loops.

Unlike other proposals that only help to establish requirements concerning the student-machine interface (Hadad, GDS, 2007; Breitman, 1998, Sutcliffe (1997), neglecting other aspects of the design and application domain, our proposal includes additional operations, also based on relationships, which are defined so that a hierarchical architecture of scenarios can be built in addition to investigating the evolution of these scenarios through simulation.

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This learning strategy is reinforced by the findings of the new studies by the Harvard-Smithsonian Center for Astrophysics (CfA) under Matthew H. Schneps leadership (Harvard College Observatory). The experimental evidence presented shows that the use of new technologies in the classroom provides significant learning gains among students who used the simulation applications of modern communication devices. For example, it is shown that students understand the unimaginable emptiness of space more effectively when they use the iPads (or other tablets) to explore 3-D simulations of the universe, compared to traditional teaching methods.

9. Conclusions

Despite the obvious limitations of the human cognitive apparatus, models can be formally evaluated and they allow reaching more reliable conclusions about the system’s behaviour and the effectiveness of certain policies.

The development of methods to explain the connection between behaviour and structure has strengthened the educational role of the modelization process as well as that of simulation using application software.

Studies on modelization as a teaching tool show that the "educational modelization" constraints are due not only to the weaknesses in the students´ scientific training but also to the teachers’ ignorance about the modelization process in both learning and scientific research.

In educational terms, the perception of an endogenous explanation of a system’s behaviour, from its interdependence and feedback structure, promotes and encourages the development of the student´s systemic thinking.

The use of new technologies as a simulation tool reinforces the change in the teaching-learning paradigm in the classroom.

The application of this learning strategy to a particular case will be part of future research on the limitations and progress in the use of modelling and simulation as teaching tools.

10. References

Acero, V., et. al. (2011). ¿Cualitativo o cuantitativo? Esa no es la cuestión: un método para el desarrollo de hipótesis dinámicas. IX Congreso Latinoamericano de Dinámica de Sistemas and II Congreso Brasileño de Dinámica de Sistemas.

Andaloro, G., et al (1991). Modelling in physics teaching: the role of computer simulation. Int. J. Science Education, No. 13(3), pp. 243-254.

Andrade, H., et. al. (2009). Framework para el desarrollo de ambientes software de aprendizaje y toma de decisiones con modelos en dinámica de sistemas. XIII Congreso de Informática en la Educación. InforEdu 2009. Habana (Cuba).

Bertrand de Jouvenel (1967). The Art of conjecture. Editor Basic Books. Michigan University.

Blomhφj, M. (2004). Modelización matemática: una teoría para la práctica. Revista de Matemáticas Vol. 23. 2. pp. 20-35, Universidad Nacional de Córdoba.

Bouciguez, M.J. et. al. (2010). Ambientes virtuales altamente interactivos para el aprendizaje de ciencias en contextos educativos. WICC 2010 – XII Workshop de Investigación en Ciencias de la Computación.

Braun, W. (2002). The system archetypes. The Systems Modeling Workbook, W. Braun, Ed.

Coyle, G. (2000). Qualitative and quantitative modelling in system dynamics: some research questions. System Dynamics Review, vol. 16, pp. 225-244.

Forrester, Nathan (1983). Eigenvalue analysis of dominant feedback loops. 1st International Conference of the System Dynamics Society, Chestnut Hill, United States.

Gilbert, J.K. (2004). Models and modelling: routes to more authentic science education. International Journal of Science and Mathematics Education, 2(2), pp.115-130.

Godet, M. (1991). From anticipation to action. A handbook of strategic prospective. Unesco Publishing. Spanish version: De la anticipación a la acción. Manual de prospectiva estratégica. Barcelona. Editorial Marcombo S.A. Spain. 1993.

Godet, M. and Durance, P. (2011). La Prospectiva estratégica: para las empresas y los territorios. Dunod and UNESCO 2011.

Gómez, D., et. al. (2009). Definición sistémica y simulación dinámica de escenarios: aplicación a la economía colombiana 2002-2007. Resource document. http://www.ecsim.org/ vista/archivos/metodologia%20y%20escenarios%20colombia.pdf.

Guilhou, X. and Lagadec, P. (2002). La fin du risque zero. Eyrolles, Editions d'Organisation. France.

Hadad, G. D. S. (2007). Uso de escenarios en la derivación de software. PhD. Dissertation. Facultad de Ciencias Exactas. Universidad Nacional de La Plata. Argentina (November).

Hestenes, D (1987). How the brain works: the next great scientific revolution. In: C.R. Smith and G.J. Erickson (eds.), Maximum Entropy and Bayesian Spectral Analysis and Estimation Problems (Reidel: Dordrecht/Boston). p. 173–205.

Huang, J. et al. (2010). An extension of loop deactivation in the behavioural method. 28th International Conference of the System Dynamics Society, Seoul, Korea.

Kahn, H. and Wiener, A. (1967). The year 2000: a framework for speculation on the next thirty-three years. MacMillan. ISBN 0-02-560440-6.

Krajcik, J., et. al. (2000). Un andamiaje de herramientas tecnológicas para promover la enseñanza y el aprendizaje de ciencias. In C. Dede (Comp.). Aprendiendo con tecnologías. Editorial Paidós. Buenos Aires, Argentina.

Lakatos, I. (1976). Proofs and refutations. Cambridge: Cambridge University Press. ISBN 0-521-29038-4

Lakatos, I. (1978). The methodology of scientific research programmes. Philosophical Papers Volume 1. Cambridge: Cambridge University Press.

Law, A. M. and W. D. Kelton. (1999). Simulation modeling and analysis. Third Edition, McGraw-Hill, New York (December).

Medina Vásquez, J. and Ortegón, E. (1997). Prospectiva: construcción social del futuro, Instituto Latinoamericano de Planificación Económica y Social (ILPES). Universidad del Valle, Cali, Colombia.

Peñaloza Figueroa J.L. and Vargas Pérez, C. (2006). (http://orcid.org/0000-0001-9109-7247 and http://orcid.org/0000-0002-2905-4569) ¿Qué debe cambiar en el aprendizaje de la estadística en las ciencias del comportamiento? XIV Taller y II Encuentro Internacional de la Asociación Española de Profesores Universitarios de Matemáticas para la Economía y la Empresa. ASEPUMA.

Peñaloza Figueroa J.L. and Vargas Pérez, C. (2009). (http://orcid.org/0000-0001-9109-7247 and http://orcid.org/0000-0002-2905-4569). Acquisition of skills and supervised and unsupervised learning of inferential statistics. 1st International Conference on Education and New Learning Technologies. EDULEARN09 Proceedings http://library.iated.org/publications/EDULEARN09. Barcelona, Spain. 6-8 July. http://library.iated.org/related/PENALOZAFIGUEROA2009ACQ. Publisher: IATED. ISBN: 978-84-612-9801-3 / ISSN: 2340-1117.

Peñaloza Figueroa J.L. and Vargas Pérez, C. (2010) (http://orcid.org/0000-0001-9109-7247 and http://orcid.org/0000-0002-2905-4569). Numeric indicators for competence-based evaluation in statistical learning. 4th International Technology, Education and

Development Conference. INTED2010 Proceedings. http://library.iated.org/publications/INTED2010. Valencia, Spain. 8-10 March, 2010. http://library.iated.org/view/PENALOZAFIGUEROA2010NUM. Publisher: IATED. ISBN: 978-84-613-5538-9 / ISSN: 2340-1079.

Peñaloza Figueroa J.L. and Vargas Pérez, C. (2013). (http://orcid.org/0000-0001-9109-7247 and http://orcid.org/0000-0002-2905-4569). Modeling and simulation workshops as a learning tool and conceptual and relational consolidation. 7th international technology, Education and Development Conference. INTED2013 Proceedings. http://library.iated.org/publications/INTED2013. http://library.iated.org/?search_text=publication%3AINTED2013&adv_title=&rpp=25&adv_authors=PE%C3%91ALOZA&adv_keywords=&orderby=page&refined_text=. Valencia, Spain. 4-5 March, 2013. http://library.iated.org/view/PENALOZAFIGUEROA2013MOD. Publisher: IATED. ISBN: 978-84-616-2661-8 / ISSN: 2340-1079.

Prigogyne, LL. (1997). El fin de las certidumbres, Taurus. Madrid.

Popper, K R, (1972). Objective knowledge: an evolutionary approach, Oxford-Clarendon Press.

Popper, K.(1934). The logic of scientific discovery. New York: Routledge, 2009. ISBN 10 0-415-27843-0.

Popper, K. (1934). La lógica de la investigación científica. Translated by Víctor Sánchez de Zavala (1ª edición). Madrid: Editorial Tecnos, 1962. ISBN 84-309-0711-4.

Schoemaker. Paul J.H. (1995), “Scenario planning: a tool for strategic thinking”, in: Sloan Management Review, Winter

Sterman, J. (2000). Business dynamics. Systems thinking and modeling for a complex World. Boston, MA, USA.

http://dx.doi.org/10.4995/muse.2015.2245
ISSN: 2341-2593

Stewart, James, Lothar Redlin. y Saleem, Watson (2007). Precálculo, Matemáticas para el cálculo. 5th. Ed., Cengage Learning.

Vargas Pérez, C. and Peñaloza Figueroa J.L. (2013). (http://orcid.org/0000-0001-9109-7247 and http://orcid.org/0000-0002-2905-4569). Modeling and simulation workshops as a learning tool and conceptual and relational consolidation. 7th international technology, Education and Development Conference. INTED2013 Proceedings. http://library.iated.org/publications/INTED2013. http://library.iated.org/?search_text=publication%3AINTED2013&adv_title=&rpp=25&adv_authors=PE%C3%91ALOZA&adv_keywords=&orderby=page&refined_text=. Valencia, Spain. 4-5 March, 2013. http://library.iated.org/view/PENALOZAFIGUEROA2013MOD. Publisher: IATED. ISBN: 978-84-616-2661-8 / ISSN: 2340-1079.

Villa O., et. al. (2007). El proceso de modelación matemática en las aulas escolares. A propósito de los 10 años de su inclusión en los lineamientos curriculares colombianos. Octavo Encuentro colombiano de Matemática educativa. Resource document. Grupo de Investigación en Educación Matemática e Historia (UdeA, Eat), University of Antioquia.