International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682
Vol.5, No.9, September 2016 DOI:10.15693/ijaist/2016.v5i9.6-12

Modelling and Simulation of Skills Acquisition and Performance of Education System

Mrs N. Messaoudi
Phd Student/ Laboratory of Physics of Materials, Microelectronics, Automation & Thermal, Faculty of Sciences, University Hassan II, Casablanca, Morocco

Pr. J. Khalid Naciri
Professor/ Laboratory of Mechanics Faculty of Sciences, University Hassan II, Casablanca, Morocco

Pr. B. Bensassi
Professor/ Laboratory of Physics of Materials, Microelectronics, Automation & Thermal, Faculty of Sciences, University Hassan II, Casablanca, Morocco

***Abstract*—The modelling of education systems based on business models is an approach that allows the analysis of education systems from different points of view, and also allows considering the control and simulation of these systems for decision support or computerization. In this paper, we propose an approach coupling the economic and educational aspects based on the definition of a meta-model suitable for training systems incorporating both the flow simulation methods used by international organizations to simulate the educational systems, as well as engineering methods for the characterization of skills production systems. The meta-model adopted in this work is based on the processor concept introduced by Kromm which is coupled with a differential equation for the mathematical modelling of the increase of competence. The applications of this model highlight his potential for measuring the performance of an education system.**

Index terms -Modelling – Competence - Training system – Performance – Simulation.

I. INTRODUCTION

Training systems are complex organizations, and several research projects propose models of these systems for various purposes, either for the establishment of a quality approach in those systems or for the computerization of processes, or design of new systems. These models are focused on the study of the performance and organization of these systems and are based on methods used for business process modelling. [1, 2, 3]. Indeed, modelling training systems based on these methods constitutes an approach of representing a training system under different points of view and allows considering the control and simulation of these systems for analysis or computerization [4]. These works have studied the implementation of the GRAI method [5], for modelling decision-making system, the MECI method [6] for modelling processes, and Olympios method [7] for the process control. Other methods are used as for example CIMOSA methods [8] or PERA [9].

However, these models are not commonly used to simulate training systems because of the high level of granularity they require and the limited number of issues that they allow to approach [10].

On the other hand, there are some basics models used as tools for decision support by organizations involved in policies and strategies definition for educational system. This is the case of the simulation tool EPSSim [11, 12] a generic model developed by UNESCO intended to facilitate the design of educational systems development plans. This tool aims to provide technical and methodological support to governments and education specialists to develop credible plans or programs of educational development. EPSSim is a demographic model, in which objectives for education are considered as decision variables and education spending are calculated as the consequence of the achievement of these objectives. This type of model basically facilitates flow simulation and cost calculation. However, they do not allow access to the overall performance of an educational system, considered in his educational and economic dimensions.

Furthermore, the development of information and communications technology for education has created, in recent years, new forms of education, such as e-learning, and blended learning coupling "classroom teaching" and distance learning or customized e-learning offering training courses adapted to each user according to his profile, his acquired skills and individual needs. To define the added value of these new forms of education, new models are developed for the design and performance simulation of this tool [13, 14].

The objective of this article is to propose an approach coupling economic and educational aspects for modelling training systems that incorporates both the flow simulation methods used by international organizations, as well as industrial engineering modelling for the characterization of the production systems of skills. This model aims to quantify the pedagogic and economic performance of a training system.

Following the theoretical framework of business process modelling [3], it is considered that a system performs transformations on inputs in order to give them added value through the use of resources, realization rules and driving data.

These transformations are carried out through a set of processes and the inputs are in this way transformed into outputs, in a similar manner, it is assumed that a training system can be modelled by a set of processes. Each process can in turn be split into processors, this is the approach adopted for the training system modelling based on the processor defined by Kromm [15]. Based on this meta-model generic processor, we make an analogy with the training system.

II. MODELLING A TRAINING UNIT

A. Description of the Model

The processor proposed has the ability to model any entity carrying out an activity in the production structure. The Meta model of the processor is as shown in figure 1.

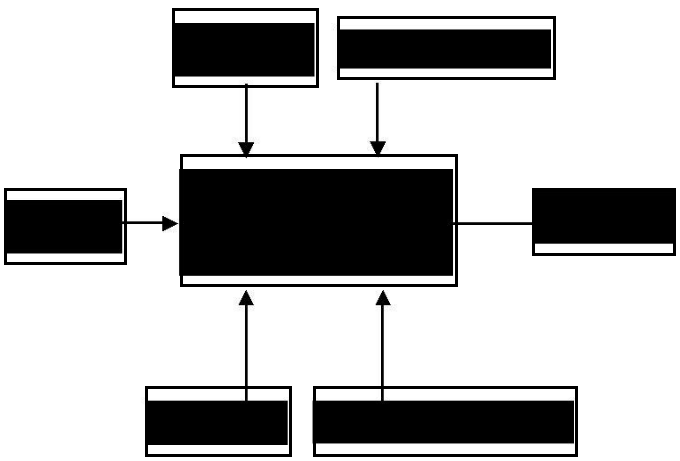


Figure 1. Meta-model generic processor defined by Kromm

Based on this meta-model generic processor, we make an analogy with the training activity. Thus, a training activity consists of a series of training units aimed at transforming inputs competencies C_i of students E_i, i varying from 1 to N, to outputs competencies C'_i of students E_i. Resources (human and material) are mobilized for the realization of transformations according to data of realization and within data of conduct.

The generic processor is the training unit considered as an activity whose purpose is to increase competencies in time. The training unit is designed in order to increase the competencies of incoming students assumed to have input reference competencies C_r, allowing them to reach a higher level to an output reference competencies C'_r on a fixed time using resources and relying on data of conduct and data of realization.

The inputs of the system are input competencies of students E_i (i = 1 ... N) attending this training unit. Each student E_i is characterized by an identifier i, an input competencies C_i, and a factor associated to his personal capacity for skills acquisition μ_i. The outputs of the system are the output competencies of students E_i (i=1...N) who have completed this training. The data of conduct are the set of rules that manage the training activity (laws, standards, training rules ...).The data of realization are all the settings related to the curriculum. Resources are all the resources used to achieve transformation (teachers, classrooms, materials ...).

B. Mathematical modelling of the increase of competence

To define transformations completed by the generic processor, it is necessary to measure the increase in competence related to the data of conduct, resources and data of realization. This relationship is the core of any education system; it determines its performance and allows a better identification of optimal rules of its operation.

Statistical studies are generally conducted to assess the impact of various parameters on the achievements or on the increase of learner's competence in a training system [16, 10]. These studies allow establishing correlations for a given system in a particular state but do not allow having an effective mathematical tool for modelling, simulation and performance evaluation purposes. However, they have the advantage of contributing to identify the key factors involved in increase in the competence. A second aspect requires the development of approaches to quantify the increase in the competence. This is one of the important stakes for many current work redefining the system of "credits Hours" of the Carnegie Foundation [17].

As the model to achieve in the context of this work should enable the simulation of a training system in terms of educational benefits and economic efficiency, it is useful to develop mathematical formulation for linking the increase in the competence to the various processor parameters. This model, given the objectives set for it, will focus on a limited set of parameters considered pertinent to the dynamic evolution of the training system. These parameters are the input competence, which is defined in the design of the training program, the personal capacity of the student's acquisition of skills, the group size and the number of hours of training.

In order to have a model taking into account these parameters, it is necessary to have a relation between increase in competencies and the selected parameters.

A training unit is typically designed by setting a reference level of competence C_r assumed to be acquired by all incoming training. Similarly, training also sets the level of output competence C'_r that students must achieve to validate their training. Thus a reference competence increase (C'_r - C_r) is thereby defined for any training activity.

The second parameter is the personal capacity of the student's acquisition skills. Indeed, each individual reacts in a way that is specific about the process of acquisition of competence. Taking into account this aspect through a coefficient μ_i, specific to each student, which reflects its ability to gain the competencies expected with more difficulty (μ_i<1) or more ease (μ_i> 1) as projected in the design of training. This parameter μ_i relates the factors associated to personal condition, family and socioeconomic situation of the student and the family's ability to follow and participate actively in his school life and socio economic conditions. It is considered when designing training that the personal capacity of acquisition of competence reference μ_r is 1. The coefficient of group size of the training, denoted by g_r is defined in the design of training by type (lessons theoretical, practical ...). Finally, the number of hours in reference to training required to increase the competence C_r of students from one level to a level C'_r denoted by h_r.

Determining the relation between increase in competencies to training time is a subject that has been studied in various studies and work [18, 19]. Mathematical modelling of increasing competence over time is one of the stakes for both the training systems as well as many other areas, such as management of business skills [17, 20] or artificial intelligence for learning by the neural network.

The educational theories of learning prove that educational processes connect the input competence to the output competence by adopting a sigmoid curve. This curve reflects a slow evolution of competency at the beginning of training, and a significant increase of competence in a given phase of training to reach saturation at the end of training unit.

For this, we consider that the time variation of competencies of a student E_i for a period of time dt evolved over time according to a Gaussian distribution centered in $h_r/2$ and whose standard deviation σ is related to the parameter α which characterizes the progressive evolution of competency during the training.

This variation can be expressed as follows [21]:

$$\frac{dC_i}{dt} = A_0 \cdot \left(e^{-\alpha\left(t-\frac{h_r}{2}\right)^2}\right) \quad (1)$$

Where A_0 is a constant given by:

$$A_0 = \frac{(C'_r - C_r)}{h_r} \cdot \left[h_r \cdot \sqrt{\frac{\alpha}{\pi}} \cdot \frac{1}{erf\left(\sqrt{\alpha} \cdot \frac{h_r}{2}\right)} \right] \quad (2)$$

By integration on a real time of training h, we obtain the analytic expression of increasing of competence of each student for one training unit, which is written as:

$$\Delta C_i = \int_0^h \frac{dc_i}{dt}\, dt = \frac{h_r}{2} \cdot \left[1 - \frac{erf\left(\sqrt{\alpha} \cdot \left(-h + \frac{h_r}{2}\right)\right)}{erf\left(\sqrt{\alpha} \cdot \frac{h_r}{2}\right)} \right] \quad (3)$$

By analogy with the studies for the assessment of prior learning [16], this relation can take into account the dependencies between increased competence and resources mobilized through a training system, including a number of hours of training and a group size training through a function h (g), as well as personal capacity of acquisition of competence of each student μ_i and their entries competences compared to inputs competences reference through a function $k(C_i/C_r)$.

The expression (1) thus becomes:

$$\Delta C_i = \int_0^h \frac{dc_i}{dt}\, dt = \frac{h_r}{2} \cdot \left[1 - \frac{erf\left(\sqrt{\alpha} \cdot \left(-h + \frac{h_r}{2}\right)\right)}{erf\left(\sqrt{\alpha} \cdot \frac{h_r}{2}\right)} \right] \cdot \mu_i \cdot k(C_i / C_r) \cdot h(g) \quad (4)$$

Behavior for $k(C_i/C_r)$:

The function $k(C_i/C_r)$ allows to take into account in the model so defined that a student entering a training unit without having the required level of competence defined by C_r will not have the same progression in terms of variation of competencies with another student who has required skills at the entrance level. In the first approximation, the introduced processor model will test different configurations to express the factor $k(C_i/C_r)$. Identification techniques may optionally be introduced to proceed to the estimation of $k(C_i/C_r)$. The expression retained to model the input competencies deficit is:

$$k\left(\frac{C_i}{C_r}\right) = \left(\frac{C_i}{C_r}\right)^2 e^{\left[1-\left(\frac{C_i}{C_r}\right)^2\right]} \quad (5)$$

This relation allows to introduce the evolution between the values 0 and 1 of the coefficient k with k = 0 if $C_i = 0$, this reflects the fact that a student who has none of the competence level required to entry can not progress during training and k = 1 if $C_i = C_r$, to take into account the fact that a student who is qualified to entry should reach the expected level of competence for output. Whereas, if a student has reached a level of competence C_i above the reference input level C_r, the benefit of training is less and allows only a small increase of competence.

Behavior for h(g).

The real size of the group of a training unit is associated to resources that can make available the institution reflected in the number of group n_r planned and the number of students pursuing this training unit, which can result a coefficient g as follows:

$$g = \frac{N}{(g_r \times n_r)} \quad (6)$$

Where g_r is the group size reference of the Training Unit, n_r is the number of available group reflecting the resources mobilized by the institution and N is the number of students attending the training unit.

The function h(g) allows to take into account in the model so defined that if the group size increases, the impact is negative on increasing the competence decreases and vice versa.

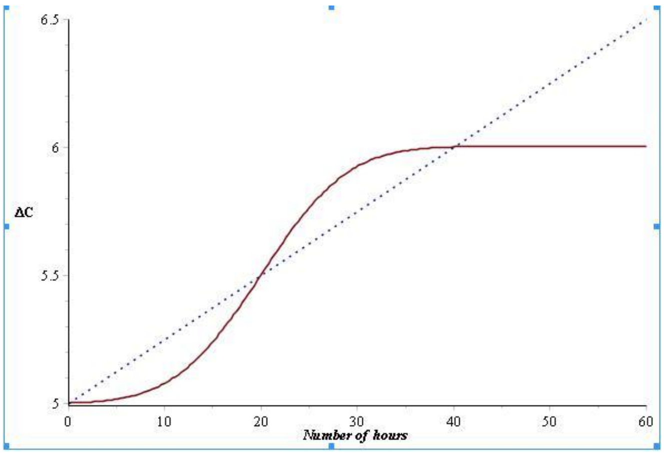
In the first approximation, the introduced processor model will test different configurations to express the factor h(g). The expression retained to model the impact of group size is:

$$h(g) = 0{,}8 + \frac{(1{,}2 - 0{,}8)}{(1 + g^4)} \quad (7)$$

This relation allows to introduce the evolution between the values 0,8 and 1,2 of the coefficient h with h = 1,2 if the number of students attending the training unit is the half of the number expected, this reflects the fact that a small group helps facilitate increased and k = 0,8 if the number of students attending the training unit is double of the number expected.

C. Application of the model:

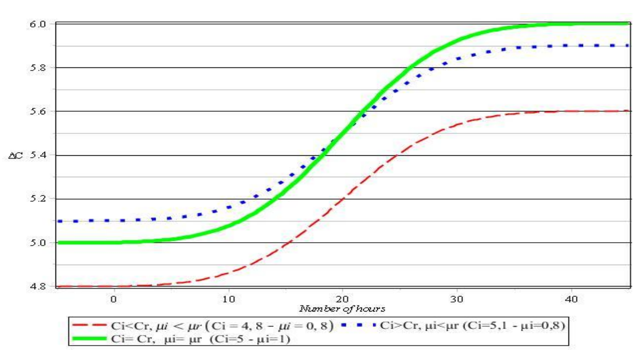
Graph 1 shows an example of increasing competence ΔC. In this case, the training program is designed to lead students to an input competence reference C_r =5 to an output competence reference C'_r =6 for a duration reference h_r=40h for students who have μ_i =1. The parameters h(g)=1 and k(C_i/C_r)=1.



Graph 1: Evolution of increasing of competence over the time (Cr=5, C'r=6, hr=40).

We note, in Graph 1, that the expression (4) can reflects mathematically evolution of competence over time. This type of evolution complies with the educational realities. Indeed, a training program is designed to lead students to an input competence reference C_r to an output competence reference C'_r for a duration reference h_r. Beyond this number of hours, further training on the same program will not result in a significant increase in competence. However, if the number of hours devoted to training program is less than the number of hours of reference, it does not allow a typical student (for μ_i= 1) to reach the output level of required competence. Thus, this relation allows the model to take into account the rate of implementation of training schedule volumes in a training system and to quantify the impact on the competence acquired by students.

A simulation of different cases of increase in competencies based on different parameters is shown by the graph2.



Graph 2: simulation of different cases of increased competence.

Graph 2 shows the impact of C_i and μ_i factors, on the evolution of student competencies. The ability of the model to take into account the impact of the student's personal capacity factor, as well as his input level of competence, will allow, when modelling a training system, to quantify the impact of these factors on performance. Note that the meta-model, so defined, allows measuring the performance level of a training unit, linking the increase of competencies C to the number of hours of training.

The definition of this meta-model also allows simulations of systems which consist of several processors connected in series and in parallel and give access to overall performance of the system based on the rules that are set for the transitions between processors.

III. Modelling a Training Program

A. Model description

A training program is considered schematically as a network of training units interconnected with transition rules. To model this program, we introduce a network of m processors connected in parallel and in series. The training units are grouped into n blocks of k processors, m = nk. For each training unit, whose reference parameters C_r, C'_r, h_r and g_r are known, we fix predecessors training units, which are the prerequisites for access to the training unit considered. Similarly, rules fix a scheduling of blocks back in time, thus each block has a predecessor.

To set an initial state of the network, a number of students i at t=0 is arbitrarily assigned to each training unit of the program. In addition, for each student and for each training unit in which he is registered, a personal capacity of acquisition of skills and an initial input competence is generated.

As a constraint in the system, a defined number of new incoming students are expected to enroll in the program every year. We simulate our training program by an example of training program with n = 3 blocs of k = 4 units each.

The simulation done is based on the following process as shown in figure2.

Graph 2simulation of different cases of increased competence.

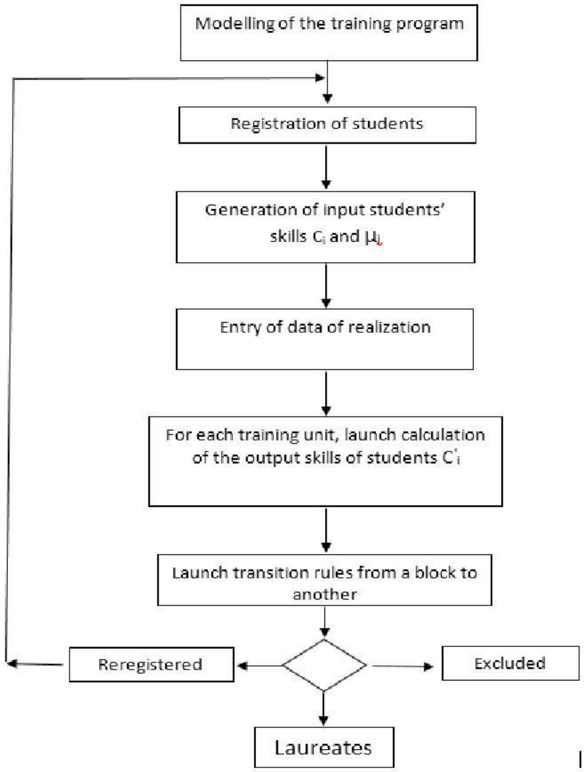


Figure 2: Process of modelling of training Program

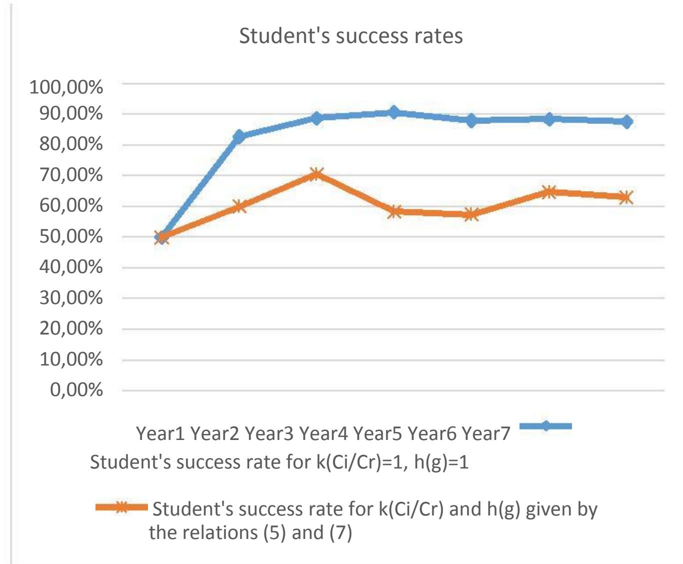
Figure 1: Process of modelling of training Program

B. Results:

The simulated program is defined as follows: n = 3, k = 4.

For each training unit, input competence reference, output competence reference, number of hour's reference and the reference group size are set. We initialize the simulation of the training program in a given academic year, denoted year1, with an arbitrary number E_s of students enrolled in level 1 and we initialize the input competence of students for each training unit to input competence reference for the considered unit. As a constraint in the system, we must enroll each year E_s new students in block1.

Graph 3 shows the temporal evolution of the success rate of the training program for various simulations.



Graph 3 Results of various simulation.

The first one analyze the impact of the personal ability of the student's acquisition of competence. We note that the success rate is around 80%.

The second one includes in addition to the impact of the personal capacity of competence acquisition, the impact of the deficit of the input competence and the impact of the group size. Therefore, we note that the success rate has decreased significantly for all levels.

In addition, this simulation allows us to quantify the competence acquired by the students for each training unit using our mathematical model of the processor. It reveals the behavior of the training program over time by calculating the number of students and their acquired competence for each training unit and for several years. Also, it shows the impact of some parameters, such as the personal capacity of student competence acquisition and the group size on the results of the system.

IV. Conclusion

The model presented allows the simulation of flows for a training program and can be extended to include several training programs thus simulating an education system. The obtained results show that the impact of different parameters on flow dynamics in the system can be analyzed.

The advantage of the model lies in its capacity to identify the competence acquired by a student in particular and in a more global way to quantify the overall performance of the system in relation to the educational and financial constraints. This simulation allows us to model the impact of other parameters on the behavior of the system (e.g. the number of training hours, the deficit of the input student competence, group size, etc.).

REFERENCES

[1]. S. Ruth et S. Aguilar, «Business process modelling: Review and framework,» International journal of Production Economics , vol. 90, p. 129–149, 2004.

[2]. D. Chen, G. Doumeingts et F. Verdanat, «Architecture for entreprise integration and interoperability: Past, present and future,» Computer in industry, n° %159, pp. 647-659, 2008.

[3]. F. Verdanat, «Entreprise modeling and integration(EMI): Current status and research perspectives,» Annual reviews in control, n° %126, pp. 15-25, 2002.

[4]. M. Abid, A. Atmani, B. Nsiri et B. Bensassi, «Modelisation and simulation of piloting's for a training organisation,» International journal of research in education methodology, vol. 2, n° %12, pp. 95-101, 2013.

[5]. G. Doumeingts, B. Vallespir et D. Chen, GRAI grid decisional modelling, P. Bernus, K. Mertins, G. Schmidt (Eds) éd., Berlin: Handbook on Architectures for Information Systems, Springer-Verlag, 1999, pp. 313-317.

[6]. C. Pourcel et D. Gourc, Modélisation d'entreprise par les processus: activités, organisation & applications, France: Cépaduès, 2005.

[7]. F. Theroude, «OLYMPIOS: un modèle pour le pilotage de processus,» chez The 3e Conférence Francophone de MOdélisation et SIMulation, Troyes, 2001.

[8]. A. Abdelmouleh, M. Spadoni et F. Vernadat, «Distributed client/server architecture for CIMOSA-based enterprise components,» Computers in Industry, vol. 55, n° %13, p. 239–253, 2005.

[9]. T. Williams, «The Purdue Entreprise Reference Architecture,» Journal Computers in Industry, Vols. %1 sur %224 (Issues 2-3), pp. 141-158, 1994.

[10]. M. Drgana et D. Ivanaa, «Business Process Modeling in Higher Education Institutions. Developing a Framework for Total Quality Management at Institutional Level,» Procedia Economics and Finance , vol. 16, pp. 95-103, 2014.

[11]. UNESCO, «Education, Policy & Strategy : Simulation Model EPSSim Version 2.1,» 2005.

[12]. E. Porta et B. Wils, «Review and evaluation of selected education projection models in use in 2006,» Education policy and data center (PHI 360), 2007.

[13]. P. SeungSoon, «Applying Petri nets to model customized learning and cooperative learning with competency,» International journal computer science and network security, p. Vol. 8 N°2, 2008.

[14]. P. Slechtova, H. Vojackova et J. Voracek, «Blended learning: Promising strategic alternative in Higher education,» Procedia social and behavioral sciences, vol. 171, pp. 1245-1254, 2015.

[15]. H. Kromm, «Contribution à une méthodologie d'analyse de la cohérence entre les objectifs de conception et d'exploitation d'un système de production,» Université de Bordeaux I, Bordeaux, 2002.

[16]. Conseil supérieur de l'enseignement, «Programme national d'évaluation des acquis,» CSE, Maroc, 2008.

[17]. R. Porter et K. Reilly, «Competency-Based Education as a Potential Strategy to Increase Learning and Lower Costs. Maximizing Resources for Student Success.,» 2014.

[18]. M. J. Anzanello et F. Fogliatto, «Learning curve models and applications: Literature review and research directions,» International journal of industrial ergonomics, vol. 41, pp. 573-583, 2011.

[19]. N. Leibowitz, B. Baum, G. Enden et A. Karniel, «The exponential learning equation as a function of successful trials results in sigmoid performance,» Journal of Mathematical Psychology, pp. 338-340, 2010.

[20]. P. Różewski et B. Małachowski, «Approach to Competence Modelling for Enterprise Knowledge Management,» IFAC Proceedings Volumes, Vols. %1 sur %245, Issue 6, pp. 1159-1164, 2012.

[21]. N. Messaoudi, J. KHALID NACIRI et B. Bensassi, «Global model for increasing skills and performanec of an education system,» chez Abstracts books of International congress on education, innovation and learning technologies, Granada, 2015.

Authors Profile

N. Messaoudi received the **engineering** degree in automatic and industrial computer from the Higher School of electricity and mechanical, University Hassan II, Casablanca, Morocco. Currently working in the field of IT with great experience in management in higher education. Her research interest includes performance of higher education, modelling and simulation, business modelling.

J. Khalid Naciri received the **PHD** degree in mechanical sciences from University Paul Sabatier, Toulouse, France. Currently, professor at Faculty of sciences, University Hassan II, Casablanca, Morocco. His research interest includes aeronautical engineering, mechanical engineering, quality assurance in higher education, modelling and simulation

B. Bensassi is a professor in physics department at faculty of science, Hassan II University, Casablanca, Morocco. He is responsible of logistics engineering master degree, Electronics, Electrical, Automatic and Industrial computing master degree as well. His actual main research interests are about modeling logistic systems, electronics, automatic and industrial computing.