Proceedings of the 2003 Winter Simulation Conference
S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, eds.

SIMULATION MODELS AS AN AID FOR THE TEACHING AND LEARNING PROCESS IN OPERATIONS MANAGEMENT

Leonardo Chwif
Marcos Ribeiro Pereira Barretto

CEPI
Unifieo
R. Narciso Sturlini, 883
Osasco, São Paulo 06018-903, BRAZIL

ABSTRACT

As the focus of the teaching-learning process moves from teaching to learning, the need for a better understanding by teachers of the psychology of learning increases in relevance. Many studies have proved the differences between students' learning styles which leads to the need for different approaches to be adopted when teaching a subject. This article offers a brief review of learning styles to show how games can be applied, particularly in Operations Management. It also proposes a taxonomy for games in Operations Management to finally focus on its application to DOSM – Didactic Operation Simulation Model. After formally defining DOSM, some practical models are shown. These experiments showed its effectiveness as an instructional technique to "teaching around the cycle".

1 INTRODUCTION

The role of a teacher has changed, in recent years, from teaching to be an enabler of learning process which takes place inside (and outside) of a student. Following Carl Jung's theory on psychological types, many researchers in Education developed different models for learning styles in an attempt to classify stereotypes in learning. A modern teacher should be aware of these studies and prepare a varied set of activities within a course to be able to reach all students on their preferred style (at least some of the time).

In Operations Management-related courses, as in general in Science and Engineering programs, teaching is still based on lectures and individual assignments, focusing on abstract analysis techniques of Science Engineering and neglecting interpersonal aspects. For instance, statistics is taught as "take 2 balls from a bag", scheduling as queue theory and so on. The failure rate for these courses are always high and students' lack of enthusiasm is an historical problem. The mathematical background must not be neglected but there are many ways to make learning a pleasant activity.

This paper discusses the use of simulation games as a complementary activity. It starts by reviewing learning styles models on section 2, to illustrate the need for "teaching around the cycle" i.e. activities to address all learning styles. Then, on section 3, a taxonomy for games in learning is proposed, allowing to determine precisely the scope of this paper. Section 4 shows some examples of the application of simulation games to Operations Management with practical results described in Section 5. Finally, Section 6 indicates directions to follow.

2 LEARNING STYLES AND GAMES

Despite their differences, researchers in Education agree on the existence of various learning styles. But the models vary.

The Myers-Briggs Type Indicator (MBTI) (McCaulley 1990) model classifies students as :

- extraverts (focus on outer world of people) or introverts (focus on the inner world of ideas).
- sensors (practical, detail-oriented) or intuitors (imaginative, concept-oriented).
- thinkers (skeptical, logical decisions) or feelers (appreciative, decision taking people into account).
- judgers (prefers rigid schedule) or perceivers (adapt to changes).

The combination of these 4 aspects results on the 16 main types. Each dimension is further classified into levels. Kolb's Learning Styles (Harb et al. 1993) sees the following 4 dimensions:

- Type 1 (concrete, reflective): need to know "why is this being taught? how is this related to me?".
- Type 2 (abstract, reflective) : need to know "what is being taught?", need a well-organized material an like to see the instructor as an expert.

- Type 3 (abstract, active): need to know "how does this work?"; a trial-and-error experience is well accepted.
- Type 4 (concrete, active): need to do "what-if" activities by their own.

The Herrmann Brain Dominance Instrument (HBDI) (Lumsdaine 1995) classifies students based on brain physiology leading to 4 types:

- Quadrant A (left brain, cerebral). Logical, analytical, quantitative, factual, critical;
- Quadrant B (left brain, limbic). Sequential, organized, planned, detailed, structured;
- Quadrant C (right brain, limbic). Emotional, interpersonal, sensory, kinesthetic, symbolic;
- Quadrant D (right brain, cerebral). Visual, holistic, innovative.

The Felder-Silverman Learning Style Model (Felder 1993) divides students into the following categories:

- sensing learners (concrete, practical, oriented toward facts and procedures) or intuitive learners (conceptual, innovative, oriented toward theories and meanings).
- visual learners (prefer visual representations of presented material--pictures, diagrams, flow charts) or verbal learners (prefer written and spoken explanations).
- inductive learners (prefer presentations that proceed from the specific to the general) or deductive learners (prefer presentations that go from the general to the specific).
- active learners (learn by trying things out, working with others) or reflective learners (learn by thinking things through, working alone).
- sequential learners (linear, orderly, learn in small incremental steps) or global learners (holistic, systems thinkers, learn in large leaps).

Finally, the Multiple Intelligence (MI) model recognizes seven different ways of learning: body/kinesthetic, interpersonal, intra-personal, logical/mathematical, musical/rhythmic, verbal/linguistic and visual/spatial.

No matter the model of your preference, the differences are clear. Most of the time in Engineering programs, the didactic strategy favors only a few styles. For instance, lectures only favors Kolb's Type 2 students, MBTI introverts/intuitors/thinker/judgers, HBDI Quadrants A and B and MI logical/mathematical intelligence.

Studies have shown 20% to 40% of Engineering students don't fall into this category. Therefore, a rich set of activities within a course should be planned to address their best learning mode, at least during some of the time. It is important also to expose students to their less preferred style as long as they have to develop learning skills in any mode. This is even more important to keep them interested in an Engineering career. The term "teaching around the cycle" was coined to describe this instructional approach, where the cycle is a reference to a graphical representation of Kolb's learning styles, as in figure 1 (Felder 1996).

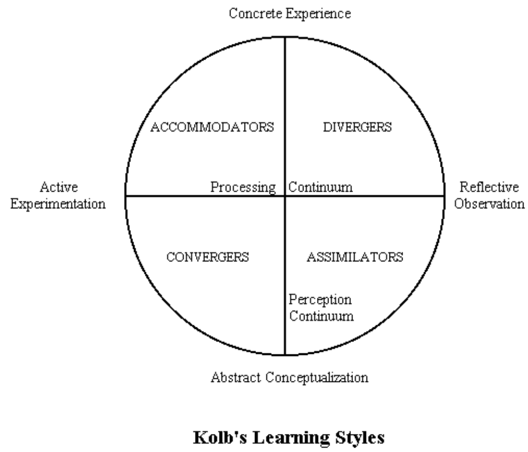

Figure 1: Kolb Learning Styles (Felder 1996)

It is here where games come into the scene. The teacher's role, as illustrated in fig. 2, moves from a "knowledge transmissor" to a "knowledge promoter/enabler", leaving room for students to experiment, derive laws, interrelate among themselves, have a visual/pictorial representation of the phenomena, exercise kinesthetic skills.

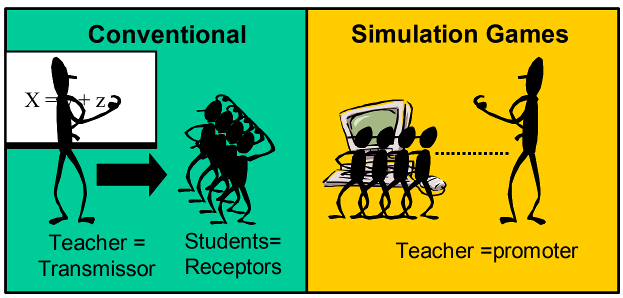

Figure 2: Schematic Figure Showing the Difference Between the Two Instructional Techniques

Table 1 (adapted from Rodrigo 1998) provides a better comparison between conventional teaching methods and the ones based on simulation games

Table 1 – More Detailed Comparison of Teaching Methods

Paradigm:	**Conventional**	**Simulation Games**
Teacher's Role	Agent	Promoter
Student's Role	Receptive	Active
Contents	Predominantly Theoretical	Real
Motivation to Learn	Contents Sequence	Curiosity, desire to solve a problem

3 TAXONOMY FOR SIMULATION GAMES IN OPERATIONS MANAGEMENT

According to Galvão et al (2000), a simulation game is a mixed feature of a game- competition, co-operation , participants and rules. Clearly these games take place on a simulated environment. They also affirm simulation games can be utilized for several purposes, but are mainly utilized for Educational purpose. Simulation games use several kinds of simulation. For instance one can build a simulation game to teach how a discrete boolean logic circuit works or to teach how to flight, referring more specifically to flights simulators. Given this overall scope for simulation games and applications, simulation game can be classified into several aspects i.e. a faceted taxonomy which are detailed below. It is important to note this classification covers not only the area of Operations Management but has a higher scope.

- **Pedagogical Aim or Scope**: According to Riis (1995), an educational simulation game could serve for the participant to gain awareness, understanding or know-how of the environment being simulated. In the first case consider the game Oligopoly (Figueiredo et al. 2001), where the participants determine the selling prices of real state assets. The main pedagogical aim in this case is to show students how competitive environments work. Furthermore it can also be used to explain complex demand-price relationship, and in this case have a purpose for understanding. Another example is the famous Beer Game from MIT <http://beergame.mit.edu/>. This can be used by students to understand complex relations of a supply chain and the importance of an overall and cooperative view. The third case (simulation for gaining know-how) could be easily exemplified by a flight simulation, whose primarily intent is to learn some operational activity (as to fly an aircraft) in a simulated environment.
- **Number of Participants/Functionality**: In this case a simulation game could be played by a single user, a group or team without specific function (all participants has the same role) or a multifunctional people or groups, for simulation games played over the Internet for instance. In this case each participant or each group has different functionalities or roles. We also named this case as Collaborative Games (Marcos 1997).
- **Nature**: In a general sense, simulation games could be played without the necessity of a digital computer, classified as non-computational games. They cannot be forgotten because are normally very simple to develop. But computational games are gaining more and more importance because they attract students' attention to a language they're familiar with and allow a teacher to audit results of student-game interaction.
- **Theme**: Regarding the main area application. Example are: electrical circuit simulation, the interaction of biological species (population dynamics) or with fluid dynamics. For the scope of this paper, only "Operations Management" is considered. Each main area can be further divided into subfacets; for "Operations Management", three of them suffice: single/basic concept, operational level, strategic level. Within single/basic concept are included all games to teach statistics or specific aspects of a theory, such as the rope-drum-buffer from Goldratt´s (Goldratt 1992) theory of constraints. Within operational level are included simulation games dealing with one specific operation, as factory-, hospital- or call center- operations. Strategic level enrolls simulation games focusing strategic levels of a given process, as in Oligopoly. Operational and strategic levels highly correlate to the kind of simulation: discrete event simulation is the basic simulation type of operational games while continuous simulation (as Industrial Dynamics – see Forrester 1958 for details) is more suitable for strategic games.

The proposed taxonomy allows to precisely determine the scope of this paper which focus on DOSM, an acronym for "Didactic Operations Simulation Model" which

- Pedagogical aim: awareness and understanding.
- Number of participants: single, group or multi-function.
- Nature: computational game.
- Theme: Operations Management, single/basic concept or operational level.

It is important also to note:

1. A DOSM is used at operational level and it is not appropriate for strategic issues.
2. A DOSM could not be used as training tools for the student to gain know-how to perform an activity like driving or flying.
3. A DOSM uses discrete event simulation as the main time advance mechanism.
4. A DOSM is a model which is always used and never built by the student, since it aims to teach a concept or an application of knowledge, and never to teach how to build a simulation model. Therefore all simulation input data must be parameterized into dialog boxes or spreadsheets, to allow a student that does not know the details of simulation software be able to operate the model. This item emphasizes also the importance of the simulation software used. To build effective DOSM a simulation software must include the possibility to enter data into spreadsheet (internal or Excel) or even have customized dialog boxes to allow the

input data. This point is illustrated by figure 3, with a example of Simul8 simulation software, a simulation software that provide all this features.

Having precisely defined this paper's scope, next section describes DOSM applications.

4 CASE STUDIES

Three DOSM cases studies are presented in what follows. The first application has the aim to teach the concept of the CLT (Central Limit Theorem). The second study is focused on explaining complex costs/benefits relationship, and it uses a fast food restaurant. The last example is concerned with showing the students the problem of scheduling a production system and the effects of choosing among several scheduling disciplines. All three models were built in Simul8 simulation software, version 9, and used in Engineering courses as described.

Figure 3: Example of Dialog Boxes/ Spreadsheets for Inputting Data into DOSM

4.1 Central Limit Theorem Explainer

This DOSM is depicted in figure 4. We have 9 queues (named from 1 to 9) and initially one single entity point of creation that chooses randomly an integer number from 1 to 9 as the entity attribute (according to pre-specified distribution). A selector is used to segregate the entities by its attribute so queue 1 only contains entity with attribute 1, queue 2 with attribute 2 and so on. In this case the drawing that will be formed by the queues will resemble the original discrete distribution. But by having a lot more than one creation with several different distributions, the Central Limit Theorem will work: The shape of the queues will resemble a normal distribution and the higher the quantity of different generators more and more this approaches to the normal bell shape.

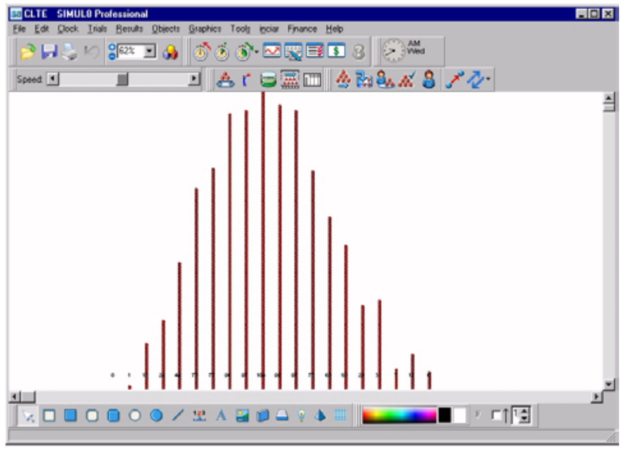

Figure 4: DOSM for Explaining Central Limit Theorem

4.2 Mac Game

Mac Game is a DOSM which primary purpose is to show students how costs and revenues interact in a complex system as a fast food restaurant. Mac Game was derived from a demo model within Simul8, but several features were added. The main objective is to set operational policies in order to maximize profit. These "policies" are controlled by the following parameters:

a) Prices of each of 4 sandwiches (Hamburger, Cheeseburger, Salad and Supreme).
b) General production or "cooking rate" (sandwiches per hour) and production mix (sandwiches production is to stock and not to order).
c) Maximum stock level for each of the 8 sandwich ingredients. A truck within a given frequency, supplies the store and completes each stock to the maximum level specified (order up-to-replenishment policy).

A number of offer-demand relationships were included and students are warned of them before trying to optimize parameters:

- price has a direct relationship with customer's arrival rate.
- difference of prices between sandwiches also affects customer's demand and hence affects the total revenue.
- unhappy customers, waiting too long in a queue, tend to "tell others" and also the demand can be strongly affected.
- a high cooking rate can lead to higher customer satisfaction (because it guarantees a high availability of sandwiches); a low cooking rate can decrease profit, since a ready sandwich has a maximum permanency or life of 6 minutes given quality standards. Sandwiches are thrown away if not consumed before this time limit.
- high stocks mean no shortage of ingredients (no loss of sales due to an ingredient's being out-of-stock) but mean also an increase of stocks operating expenses.

Mac Game is depicted in figure 5.

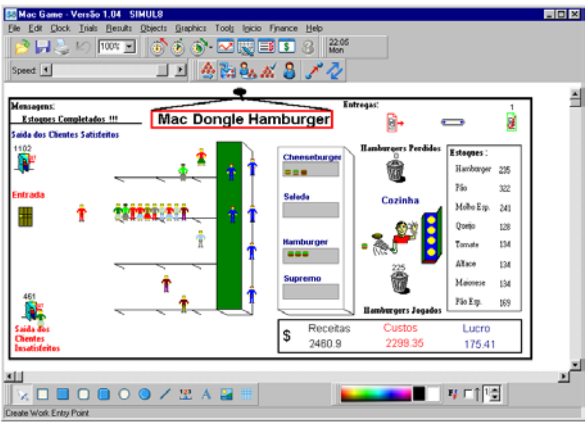

Figure 5: DOSM for Illustrating Complex Costs & Revenues Relationships

As the major indicators Mac game shows general revenues, costs and profit. It also provides detailed reports such as number of clients in each queue, satisfaction level, detailed costs, etc.

4.3 Sequeum

SEQUEUM is a DOSM whose aim is to show students how hard the scheduling problem is to solve and allow them to experience with several scheduling rules to see how performance is affected by changing these rules. The model includes 5 work centers and 5 families of parts. Each family has its own route. It is possible for the student to change the priority (selection) rule for each work center.

The rules for each work center considered in this DOSM were:

- FIFO: First In First Out.
- LIFO: Last In First Out.
- LPT: Less processing times.
- MDD: Minimum Due Date.
- ALEA: Random Order.
- LDSQ: Less Dynamic Slack with queue.
- LSS: Less Static Slack.

Several performance measures are calculated encompassing work centers utilization, production horizon (WIQ or work in queue), queuing time, processing time, maximum and average WIP, number of late and early orders, maximum and average delay or advance of orders and cost of delays. SEQUEUM DOSM is illustrated by figure 6.

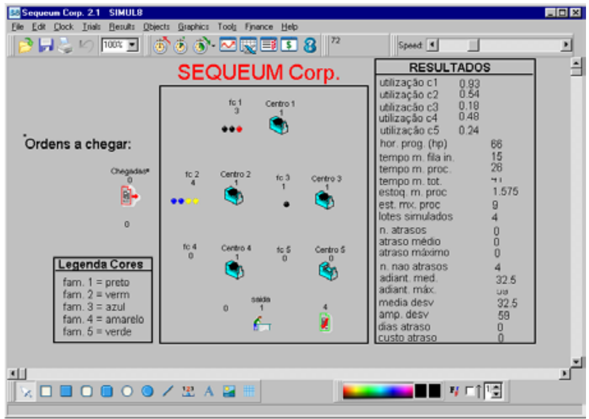

Figure 6: DOSM for Showing the Problem of Production Scheduling

All the models discussed here is available at <http://support.SIMUL8.com/library/papers/chwif>.

To run the model it is necessary to have Simul8 Viewer Simulation Software. It is free and the link is <http://www.simul8.com/viewer/>.

5 APPLICATION AND RESULTS

These DOSMs were applied to several classes of different courses at different levels. MAC GAME is being applied to 3rd year (of 5 years) Industrial Engineering, inside the Operations Research course. SEQUEUM is being used to teach to Operations Management MBA program.

The application of these DOSMs showed that:

a) there was a substantial amount of increase of interest on the subject being exposed trough games, demonstrated by reports on time dedicated to the course.
b) students demonstrated a higher level of commitment to assignment; some of them did much more that they were initially requested to do in terms of experimentation and were proud to present their

findings to others and to the instructor. It also generated a lot of more questioning than of a regular teaching method, although this observation was not audited. For instance, on MAC GAME, students were initially requested to spend 4 hours (both graduate and undergraduate), but reported spending from 6 to 20 hours, showing their interest making more analysis than they were requested to.

c) during the initial class lab activity with groups of 2 students when experimenting with MAC GAME, it has been clear to observe students interaction within their 2-students group and also between different groups, vividly discussing their findings.

This suggests, as the work of Randel (1992) indicates, that simulation are at least as effective as other methods for teaching.

6 SUMMARY, CONCLUSIONS AND FUTURE WORK

This article was concerned with the definition and applications of Didactic Operations Simulation Models, whose main objective is not to substitute formal instructional methods but to serve as a complement, favoring learning styles other than Kolb´s type 2 students.

The main conclusion up to this point is that a DOSM is a very effective instructional technique because students experience with a model as if they experienced in real life. This brings a totally new dimension to the teaching/learning process. The problem is that not all teachers are accustomed to this kind of instructional technique, and sometimes reluctant to adopt this instead of a formal teaching method. This could be explained by either the unawareness of the simulation possibilities or the operational difficult that this process requires (e.g. labs with computers and simulation software). An way to overcome this issue is to make more DOSMs available to free download as the ones described in this paper. A DOSM repository has been created by the authors at <https://sourceforge.net/projects/dosmrep/> and it is open for contributions.

This is an on-going work; more experiences are required to prove the real effectiveness of the DOSM to the learning process. Future work includes the development of new DOSMs to various situations and establish a well defined process to compare the learning curve of a specific subject with and without the aid of DOSM. As the next step, a controlled experiment is currently being developed to clearly evaluate if the learning is more efficient when it is promoted with the aid of DOSMs instead of only standard teaching technique, according to student's learning style. In this case DOSMs models will help teach material handling equipments concepts. The evaluation of learning in both cases (by games and conventional) will be assessed by three independent instruments: written examination, observation of interest and questioning level during classes and interviews. Students will be also submitted to learning style classification. Results will be shown as soon as available.

ACKNOWLEDGMENTS

The authors would like to thank the Brazilian's funding agencies (CAPES, CNPQ and FAPESP) for their support to national research.

REFERENCES

Felder, R. M. 1996. Reaching the Second Tier: Learning and Teaching Styles in College Science Education, *J. Coll. Sci. Teaching, 23*(5), pgs. 286-290, 1993.

Felder, R. M. 1996. Matters of Style. *ASEE Prism*, 6(4), pgs. 18-23, 1996.

Figueiredo, R. S. et al. 2001. A Introdução da Simulação como Ferramenta de Ensino e Aprendizagem, Enegep (Encontro Nacional de Engenharia de Produção), Salvador, Bahia.

Forrester, J. W. 1958. Industrial Dynamics: a Major Breakthrough for Decision Makers. *Harvard Business Review* 36(4):37-66.

Galvão, J. R. et. Al, 2000. Modeling Reality with Simulation Games for Cooperative Learning", In *Proceedings of the 2000 Winter Simulation Conference*, 1692 – 1698, Ed. J.A Joines,, R.R Barton, K. Kang and P.A Fishwick

Goldratt, E. M. "The Goal: A process of Ongoing Improvement". North River Press, 1992.

Harb, J. N., Durrant S.O., Terry R.E., 1993. Use of the Kolb Learning Cycle and the 4MAT System in Engineering Education. *J. Engr. Education, 82*(2), pgs. 70-77, 1993.

Lumsdaine, M., Lumsdaine, E., 1995. Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring. *J. Engr. Education, 84*(2), pgs. 193-204, 1995.

Marcos, A. 1997. Modelling Cooperative Multimedia Support Software Development and Stand-Alone Environment, Phd. Thesis, Darmstat Tech University, 1997.

McCaulley, M. H. 1990 The MBTI and Individual Pathways in Engineering Design. *Engr. Education*, *80*, p.537-542, 1990.

Rodrigo, M. J. 1998. Domínios do Conhecimento da Prática Educativa, vol 2, Ed. Ática, São Paulo,

Randel, J. B. Morris, C. Wetzel and B. Whitehill, 1992 "The Effectiveness of Games for Educational Purposes", Simulation & Gaming, 23.

Riis, J., Hohansen J. and H. Mikkelsen, 1995. Simulation Games and Learning in Production Management: an Introduction, University of Aalborg, Denmark, Chapman & Hall, England.

AUTHOR BIOGRAPHIES

LEONARDO CHWIF graduated in Mechanical Engineering (Mechatronic Specialization) in 1992 at the University of Sao Paulo and got his M.Sc. degree in 1994 and his Ph.D. in Simulation in 1999 from the same University. He spent a session at Brunel university as a research visitor at the Centre for Applied Simulation Modelling. Upon graduation Dr. Chwif joined the Brazilian branch of Mercedes-Benz truck manufacturer and then he joined the Brazilian branch of Whirlpool Corporation. Currently he is C.E.O of Simulate Simulation Technology. Dr. Chwif also teaches an introductory graduate simulation course at Mauá School of Engineering and a simulation course at specialization level at University of São Paulo. He also a teacher and researcher with CEPI (Information Technology Research Center) at Centro Universitário FIEO (Unifieo). His email is <leochwif@usp.br>.

MARCOS RIBEIRO PEREIRA BARRETTO graduated in Electronic Engineering in 1983. He got his M.Sc. degree in 1988 and his Ph.D. in 1993, both from the University of Sao Paulo. He is a professor and researcher with CEPI (Information Technology Research Center) at Centro Universitário FIEO (Unifieo). His email is <mrpbarre@usp.br>.