Proceedings of the 2013 Winter Simulation Conference
R. Pasupathy, S.-H. Kim, A. Tolk, R. Hill, and M. E. Kuhl, eds

INTERACTIVE LEARNING OF MODELING AND DISCRETE-EVENTS SIMULATION THROUGH LEGO® PARTS

José Arnaldo Barra Montevechi
Fabiano Leal
Rafael de Carvalho Miranda
Tábata Fernandes Pereira

Federal University of Itajubá
Avenida BPS, 1303, Bairro Pinheirinho
Itajubá, Minas Gerais, 37500 903, BRAZIL

ABSTRACT

A discrete-events simulation course should develop in its students not only the abilities related to the programming language and statistical analysis, but also the ability to create an abstract of a real system into a model system. Thus, this paper has the objective to develop and evaluate an educational dynamic project for discrete event simulation courses, which are capable of developing the student's ability to perform abstraction and representation of real systems in a conceptual and computational model. To meet this objective, Lego® was used in the educational dynamic. For the evaluation of the motivation presented by the students in the dynamic, the ARCS (Attention, Relevance, Confidence, Satisfaction) technique was used together with an Instructional Materials Motivational Survey (IMMS) questionnaire. An indicator was established to measure the student's utilization and/or knowledge gained. The results demonstrate that the dynamic reached its objective, presenting a high utilization in the motivational criteria analyzed.

1 INTRODUCTION

Modeling and simulation is a research method widely debated in the existing literature on the topic. Law (2006) states that the use of simulation models comes to directly substitute experiments in real systems (existing or not), in which the experiments turn economically unviable, or even impossible to conduct.

Although the name "simulation" suggests merely the construction of a computational model, this research method involves different phases. Montevechi et al. (2010), Banks (1998), and Law (2006) presented a method in simulation, dividing it into three phases: design, implementation and analysis.

These phases are characterized mainly by translating a real system to be simulated into three types of models. The conceptual phase is characterized by the construction of the conceptual model, which represents the abstraction of the actual system, recorded visually. From this conceptual model, the computational model is constructed by means of simulation software. This model occurs in the implementation phase. Finally, given that the computational model was duly verified and validated through techniques present in the literature (Sargent 2009), it is said that the computational model is apt to complete the experiments, namely, it is said that the model is operational (analysis phase).

According to Kleijnen (1995), the complete vision of the modeling and simulation process involves art and science. Based on this affirmation one can note that a training course in modeling and simulation should not be limited to only developing in students their abilities related to the use of the programming language and statistical analysis. The students should be capable of abstracting the actual system into the model form. This abstraction, with strong characteristics of art and science, should be considered an abil-

978-1-4799-2076-1/13/$31.00 ©2013 IEEE

ity to be developed in students that wish to elaborate simulation projects.

In addition, this research paper possesses the specific objective to assess an educational dynamic for the discrete events simulation course, which should be able to develop in students, the ability to abstract and represent real systems into a conceptual and computational model.

Furthermore, this paper possesses the specific objective of evaluating the dynamic developed, for the purpose of measuring the characteristics that were beneficial or unbeneficial to the teaching-learning process. For this reason, the ARCS (Keller 2009) method will be used; which evaluates the educational activity according to four elements: attention, relevance, confidence and satisfaction. This evaluation will be done through the IMMS (Instructional Materials Motivational Survey) instrument.

The expectation is to utilize this teaching dynamic in discrete-events simulation courses, independent of the simulation software chosen..

2 CONCEPTUAL MODELING BY MEANS OF THE IDEF-SIM TECHNIQUE

Conceptual modeling corresponds to a phase of discrete-events simulation, as shown by the authors Law and Kelton (2000). The creation stage of the conceptual model is the most important aspect of a study of stimulation (Kotiadis and Robinson 2008).

For Hernandez-Matias et al. (2008), there is not just one conceptual modeling method that can completely model a complex manufacturing system. As a result of the limitations of these techniques, different integrated methods of modeling have been developed.

The conceptual model should be a description independent of simulation software. For Brooks and Robinson (2001), the conceptual model is able to guide the collection of data in order to define the collection points in the process, streamlining the subsequent construction of the computational model.

The use of process mapping techniques is common in conceptual modeling, for example, a flowchart, IDEF (integrated definition methods), DFD (data flow diagrams), UML (unified modeling language) among others. It can be perceived in published simulation projects that many times the benefits of the conceptual model are rarely explored, mainly because these mapping techniques were not conceived while focusing on the simulation logic.

Seeking a better use of the conceptual model, the work of Montevechi et al. (2010) presents a modeling technique with a focus on the simulation logic, called the IDEF-SIM (Integrated Definition Methods-Simulation). This name was given because the technique is an adaptation of the symbols of IDEF with new elements, searching for a conceptual representation closer to the simulation logic. Table 1 shows the symbolism of IDEF-SIM.

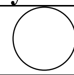
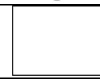
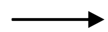
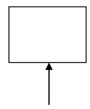
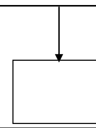
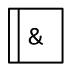
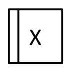
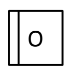
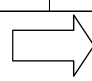
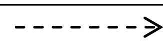
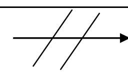
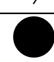
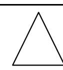
3 INTERACTIVE LEARNING AND MOTIVATION

Authors such as McIntyre and Wolff (1998) already highlighted in their work that students do not learn simply by receiving information, but learn constructively through a process of reflection on the material, and interaction with it, thus creating an understanding. Thereby, interaction is an important ingredient in effective learning, permitting the student to be engaged and reflect about problematic and interesting questions. This interactive learning can be made operational through educational games.

Educational games represent a superb tool in the area of education. Studies about this topic have increasingly become more frequent in the academic field. An expectation exists among professors that educational games may bring benefits for the teaching and learning process. Several games were already developed and are utilized in different levels of teaching in different disciplines (Prensky 2001; Garris, Ahlers, and Driskell 2002).

Nevertheless, although there are indications that educational games may be tools able to enhance the teaching-learning process (Prensky 2001; Garris, Ahlers, and Driskell 2002), and that this type of resource attracts the attention of professors and students, the degree to which certain educational games contribute to this process is often unknown.

Table 1: Symbols used in IDEF-SIM.

Elements	**Symbols**		**Origin of Technique**
Entity			IDEF3 (mode of describing the transitions)
Sites			IDEF0
Flow of the entity			IDEF0 e IDEF3
Resources			IDEF0
Controls			IDEF0
Rules for parallel flows and/or alternatives		Rule AND	IDEF3
		Rule OR	
		Rule AND/OR	
Transport			Flowchart
Explicit Information			IDEF0 e IDEF3
Input stream in the modeling system			
Final end point of the system			
Connection with other figure			

Currently, the evaluation of educational games generally is limited and, at times, absent (Connolly, Stansfield, and Hainey 2007). Hays (2005) comments, that in many cases the decision of using educational games is based on assumptions of its benefits, rather than being based on more formal and concrete reviews. Some researchers, based on different types of evaluation of educational games, have proposed evaluation models, like Kirkpatrick's model (1994), the ARCS model (Keller 2009), and the taxonomy of Bloom (Bloom 1956, Chapman 2013).

In the educational field, the motivation to learn is an essential element in any system (Keller 2009), for this reason the learning environments need to be designed carefully to provoke an adequate level of motivation in students (Huang, Huang, and Tschopp 2010). According to Keller (1993), there are common principles found in the existing literature about motivational theory in the learning process. He identified and classified them into the following categories: attention, relevance, confidence, and satisfaction. After a few years of research, these principles became known as the ARCS model (Attention, Relevance, Confidence, and Satisfaction). The instructional model was expanded (Keller 1987), and other variables, precisely will and self-regulation were added, for the purpose of guiding behavior and attitudes that could help students overcome obstacles and persist in their goals (Keller 2009).

The ARCS model has its focus on the interaction between students as well as the learning environments, and is derived from the expectation-value theory (Keller 2009). This theory indicates that expectation (which is connected to a subjective probability of an individual to obtain success) and values (which are connected to the satisfaction of personal necessities or motives) are key determinants of employee effort in an activity (Dempsey and Johnson 1998, Keller 2009).

ARCS is an acronym that identifies 4 important criteria so that one is able to motivate the students in their learning: Attention, Relevance, Confidence, and Satisfaction (Keller 2009). Hereinafter these criteria will be explained.

Attention: Refers to student's cognitive responses to instructional stimuli (Huang, Huang, and Tschopp 2010). Attention is a motivational element and also a pre-requisite for learning. The challenge is to obtain and maintain a satisfactory level of attention of the students for the extent of a period of learning (Keller 2009).

Relevance: While necessary, the attention and curiosity of the student are not sufficient conditions to motivate the student. He or she also needs to know that the educational proposal will be consistent with his or her objectives, that he/she will be able to connect the content of his/her learning with his/her professional or academic future. If a good answer is not presented, one is facing a problem of relevance (Keller, 2009). Also it represents the level of association that the students are able to perceive between their previous knowledge and the new information (Huang, Huang, and Tschopp 2010). This principle is linked to the student's perception in relation to the content learned.

Confidence: The third strategy is related to creating positive expectations in the students. This can be achieved by providing experiences of success stemming from their own abilities and effort. This factor has influence in the persistence of the students (Keller 2009; Huang, Huang, and Tschopp 2010).

Satisfaction: The students need to have positive feelings about their experience of learning, and this can come with rewards and recognition. It is also recommended to provide opportunities as early as possible, for students to apply what has been learned. The students should feel that the effort for their studies was appropriate and that there was consistency between objectives, content, and testing (Keller 2009; Huang, Huang, and Tschopp 2010).

This model has been used in various studies in order to evaluate the motivation of the students to utilize educational materials. It was already validated for use in interactive environments, and some studies already applied the model in the context of educational games (Huang, Huan, and Tschopp 2010).

In order to be utilized in the evaluation of materials, Keller developed an instrument named Instructional Materials Motivational Survey (IMMS) (Dempsey and Johnson 1998), which consists of a questionnaire to be applied after which the students use some type of educational material. Huang et al. (2006) reported positive points in relation to the validation of the instrument.

IMMS utilizes a Likert scale with 36 items. It is a questionnaire given to the participants and asks that they respond to each question according to the material studied. Each response of the participants is given between 1 (Not true) and 5 (True). There are 10 items of the instrument considered reversed, i.e. if the participant marks the item as 1 (Not true) the score is marked as 5, and if the participant marks the item as 5 (True) the score is marked as 1. These are negative statements about the activity, and for this reason the score is reversed. They are asked 12 questions related to attention, 9 to relevance, 9 to confidence, and 6 to satisfaction (Keller 1993). Many researchers like Üççül (2006), Pittenger and Doering (2010), Huang et al. (2009), among others, used this technique in their studies.

4 EDUCATIONAL DYNAMIC

4.1 Presentation

The dynamic was named "mousetrap dynamic", due to the final product which was put together by the students, a mousetrap. For the fulfillment of this dynamic, a collection of assembly pieces by LEGO® was used.

The LEGO® system is a toy which has the concept based on parts that are able to be put together in innumerable combinations. Created by Ole Kirk Christiansen, the LEGO® pieces are plastic pieces produced on an industrial scale since the middle of the 1950s, popularized throughout the entire world since then.

The LEGO® products are found in mass in large educational institutions in developed countries, starting at pre-school, where the traditional product lines entertain the young children and stimulate their concentration and creativity; until the university level, where technological product lines like LEGO Technic and LEGO Mindstorms permit the students to perfect design, robotics, and electro-mechanics (Lindh and Holgersson 2007).

In this dynamic the LEGO Mindstorms assembly collection was used, accompanied by a collection of extra pieces called LEGO Resource Set. The final product of this dynamic is a mousetrap, whose detailed design is available at http://www.nxtprograms.com.

The dynamic was applied in an education laboratory, which offered four tables and chairs. The original assembly project of the mousetrap was divided into seven phases of assembly, consisting as such, of seven work posts (each work post was assigned to one student). Figure 1 shows the kit used for the dynamic.

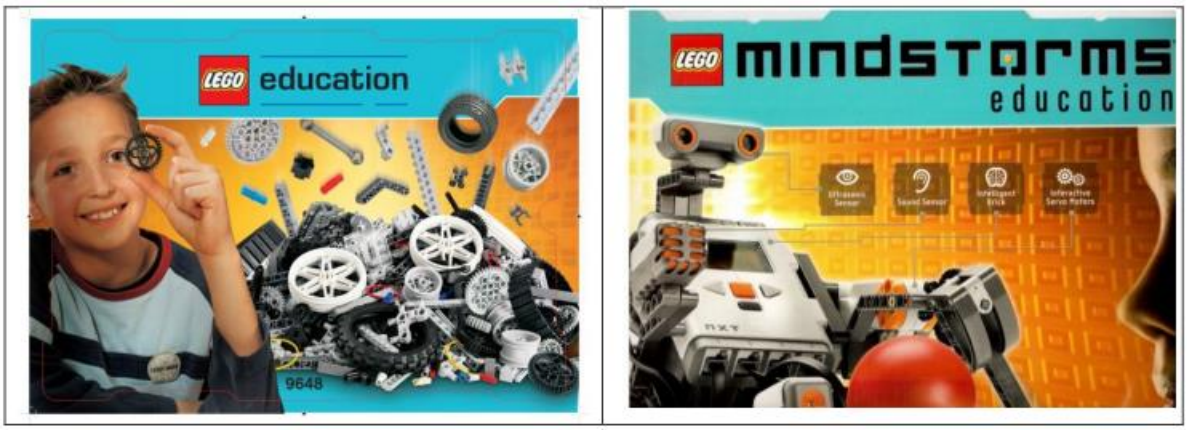


Figure 1: Kit utilized for the dynamic.

4.2 Conceptual Modeling and Observed Aspects

At the onset of the dynamic, only operators 1, 2 and 4 initiated their respective models. Operator 1, at the close of his model, arises from his chair and takes his assembled part to the kanban A**.** This kanban is a delimited space on a piece of paper, with the capability to store only one piece. At the same time, operator 2, at the close of his model, stands up from his chair and takes his mounted part to kanban B, also with the capability of only one unit. Operator 4, finishes his model, and also walks from his chair with his mounted part to kanban D.

Operator 3 awaits the supply of kanbans A and B in order to start his installation (union of the parts submitted by operators 1 and 2). Operator 3, at the end of his installation, gets up from his chair and takes his mounted part to kanban C.

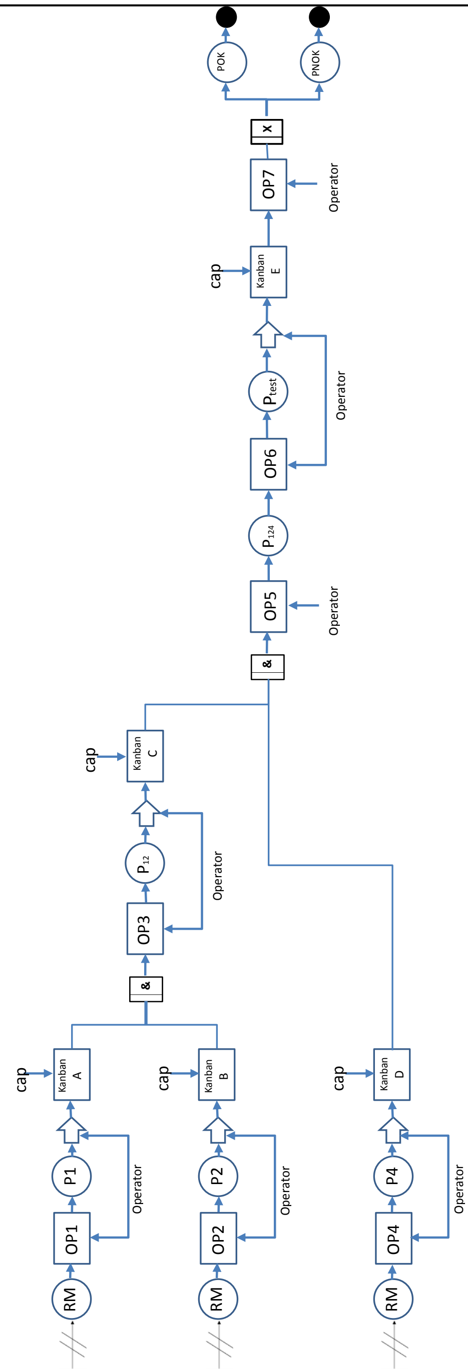
Operator 5 awaits the supply of kanbans C and D in order to start his installation (union of the parts submitted by operators 3 and 4). Operator 5, at the end of his installation, gets up from his chair and takes his mounted part to operator 6 (in this there is no kanban).

Operator 6, upon receiving the mounted piece of operator 5, finishes the product. Hereafter, this operator gets up and brings the product to kanban E. Operator 7 withdraws the installation from kanban E and performs the test of the mousetrap, coupling it to a microcomputer previously programmed. After it is coupled with the microcomputer, the mousetrap is triggered by the student’s hand. This movement indicates that the parts were properly put together along the assembly line.

The number of mousetraps assembled would depend on the number of LEGO® collections available for the dynamic. It is important to leave the pieces separated in advance, before the assembly. Beyond the seven students that directly participate in the assembly, other students assume the role of timekeepers in order to get the times of each operation and the transportation involved.

At the end of the assembly, with the assistance of the professor, the students should assemble the conceptual model, utilizing the IDEF-SIM technique. At this moment, the students develop the capacity of abstraction, logging the real process that they have witnessed in a standardized visual representation. The elaboration of this conceptual model is done by means of a discussion with all involved students. The principle elements to be perceived by the students and represented in IDEF-SIM are the following:

- Entrance points of the model: It is important that the students identify in the real system the points of entrance of the raw material. The workstations are characterized by initiating the work soon after the beginning of the simulation period, without depending on other workstations. Operators 1, 2 and 4 (OP1, OP2, and OP4 in accordance with Figure 2) fit into this situation. The entities (MP) that arrive at these sites in the IDEF-SIM are characterized by the input jack (entrance flow in the model, as shown in Table 1).
- Sites which modify or alter its lead time in the flow chart: In this category all of the operations and all of the kanbans fit. These locations are registered in the IDEF-SIM via rectangles. Information considered important about control should be connected to the sites (rectangles) via arrows pointing above. One important piece of information for simulation is the capacity of the kanbans.
- Entities processed in the real system: At this moment the students should identify the transformations which occurred in the raw material and in the installations which originated during the process. Once they are identified, these entities are represented by circles in the IDEF-SIM model.
- Transportation: During the dynamic the students responsible for operations 1, 2, 4, and 6 had to shift around the classroom in order to deliver the assemblage to the subsequent workstation. In the conceptual model, the students registered this transportation via the defined symbol (the symbol of transportation, shown in Table 1).
- Performance of the Resources: In a simulation models it is important to define the attributes of each resource. In this dynamic, the resources are the actual operators (students). Thus, the students should record in the conceptual model of IDEF-SIM the resources utilized at the sites and during the transportation. This recording is done via the arrows that touch the symbols for location and transportation below. It can be noted that in the IDEF-SIM the operators responsible for the resources are also responsible for the operations, which will result in a significant restriction of the computational model.
- Converging conjunctive paths: To observe the system, the students perceived that the operators 3 and 5 each depended on two different entrances. Operation 3, performed by operator 3, could only occur if the pieces P1 and P2 were respectively available in the kanbans A and B. This situation can be exemplified in the situation where operator 1 already transported piece P1 to kanban A, but operator 2 has not yet transported piece P2 to kanban B. Thus operation 3 must wait. The same situation can be considered in operation 5, which depends on pieces P12 and P4. IDEF-SIM represents these situations via the convergent junction conjunctive AND (&).
- Diverging paths (disjunctive): By observing the system, the students perceived that operation 7 (test of the mousetrap) can approve the mousetrap (POK) or disapprove the mousetrap (PNOK). This rule is represented in the IDEF-SIM model by the divergent junction, disjunctive OR (X).



Abbreviation	Meaning
RM	Raw material (Lego pieces)
OPn	Operation n
Pn	Piece n
Pnmo	Part from the assembly of the pieces n, m, and o
Ptest	Finalized part, awaiting quality test
POK e PNOK	Part approved by the test and part not approved by the test (NOK)
Cap	Capacity of the kanban in entities

Figure 2: IDEF-SIM generated in the dynamics from the abstraction of the students.

4.3 Computational Modeling

At this stage of the dynamic, Promodel 2011®, simulation software was used. However, the use of other software in the computational modeling of this dynamic is not impeding. The student should be qualified to accomplish the computational model independent of the software that may be selected. The choice of the technique of conceptual modeling of IDEF-SIM presents this characteristic of independence of simulation software. The commands that perform the logic represented in the IDEF-SIM are characteristics of each software. As an example of this applicability of the IDEF-SIM model with other simulation software, one can cite the work of Rangel and Nunes (2011), which utilized the IDEF-SIM model predating the computational modeling with the Arena software.

Therefore, after students' participation in the assembly of the mousetrap and the elaboration of the conceptual model in IDEF-SIM, the students received the mission to construct a computational model of the system which they witnessed. Figure 3 exemplifies a part of the IDEF-SIM model where the entities P1 and P2 will be combined in the operation OP3, resulting in the new entity P12. In the computational modeling in Promodel 2011®, the entity P2 is directed at operation 03 (OP3). Arriving at this location, the "operator 3" is utilized (GET operador_3) to cause the union of part 2 with part 1 (P1 JOIN 1). This union consumes a certain amount of time, timed in the dynamic, in this case approximately 2 minutes (MIN WAIT 2).

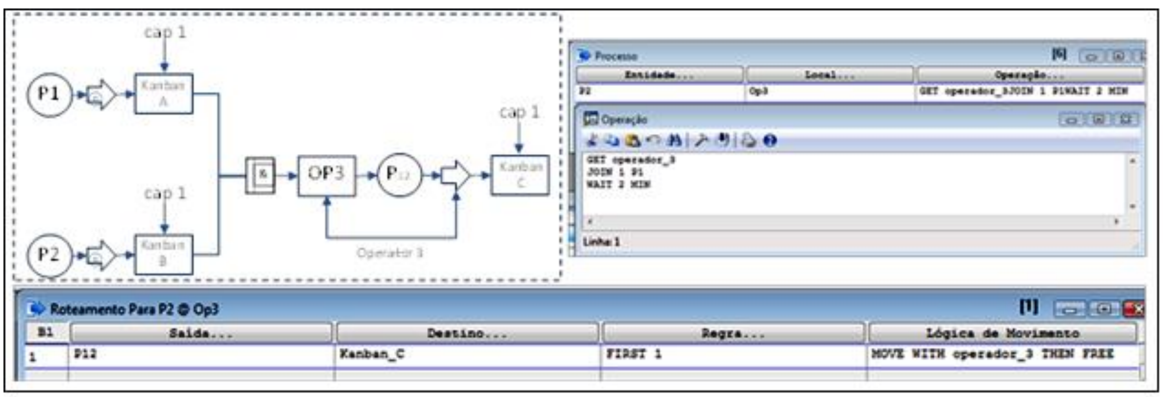


Figure 3: Conversion of a part of IDEF-SIM into a computational model.

After this union, the new entity P12 is directed at kanban C, via the transportation completed by the actual operator 3 (MOVE WITH operator_3 THEN FREE).

The objective of this stage of the dynamics is to show the students the importance of the conceptual model in the composition of the computational model. The logic used in the abstraction of the real system in the conceptual model can be confirmed as being the same logic used in the computational modeling, simply through the selection of specific commands of each simulation software.

4.4 Evaluation of Motivation of the Dynamic

For this evaluation, the IMMS instrument was used, which will assess motivational aspects, and not specifically the level of student understanding. The IMMS values were not used for the evaluation of the assimilated content, given that a new experiment where control groups would be submitted to evaluations, would be required. The questions used in the questionnaire of this research project were adapted from Üççül (2006), in accordance with the parameters of the dynamic presented. The students responded to the questions, using "1" for "totally disagree", "2" for "partially disagree", "3" for "partially agree" and "4" for "totally agree". The questionnaire used in this paper contained 36 questions in total.

As an example, one can cite a question relative to the relevant criteria, in which the student evaluates, according to the scale cited, the following situation: "Could I relate the content of this dynamic with things that I have already seen, done, or thought in my life?"

Since the answers of the Likert scale in this research project vary from 1 to 4, one obtains the minimal score of 36 and the maximum score of 144. The minimum and maximum scores vary for each criterion (ARCS) since these do not exhibit the same number of items. No norms exist for this analysis. There are no expectations of distribution of the answers. The score is given based on the sum of the answers for each criteria and the criteria in general.

The questionnaires were delivered to the participating students of the dynamic. The sum of the scored answers to the 36 questions was calculated for each student. Afterwards, the average of the sums of the scores of the students was calculated.

$$p = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} R_j\right).\frac{1}{n}$$

where:

p = average score achieved;

n= number of students that responded to the questionnaire;

m= number of questions used in the questionnaire;

R_j = score associated to the jth answer.

A specific indicator was appointed for the evaluation of the dynamic and the motivational criteria, the named indicator is (KG) for "knowledge gained". This indicator considers 100% of the cases where the students scored the question with the maximum score. The KG indicator is the normalization of p for a percentage scale, as shown in Figure 4.

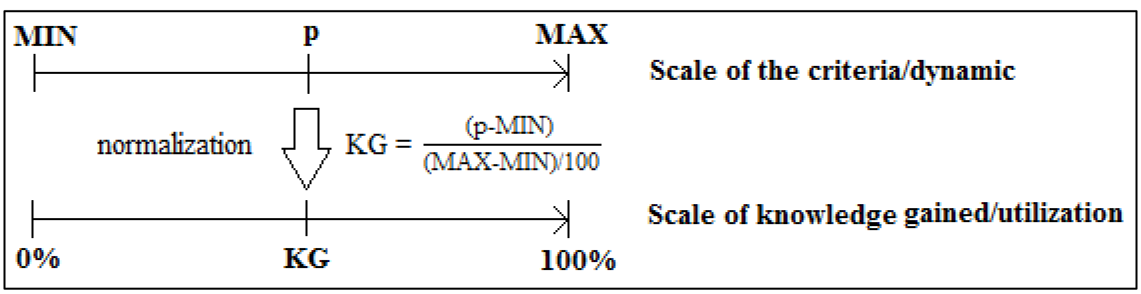


Figure 4: Indicator KG, calculated from the normalization of p.

The indicators p and KG were calculated for the dynamic as a whole and for each of the four criteria of motivation. The normalization of each indicator p of the four criteria were calculated, thereby generating the KG of each criterion, in a similar form as presented in Figure 4. The values of KG, as well as its acquisition are registered in Table 2.

The value of KG demonstrates a large motivation presented by the students who completed the educational dynamic. These values confirm the applicability of the dynamic as a didactic instrument.

Analyzing the criteria in an isolated fashion, it is perceived that there is a major difficulty for the students in relation to confidence. Although the value of knowledge gained (KG) presented by the criterion confidence (C) has been high, this value is low in relation to the rest of the criteria. This can be explained by the fact that the dynamic has been applied in an introductory course of simulation, in which the students still do not have experience in conceptual modeling or computational modeling. Nevertheless, it is considered a satisfactory use of the criteria confidence.

Table 2: Obtaining the indicator (KG) “knowledge gained” for each criterion and for the dynamic.

	Attention (A)	**Relevace (R)**	**Confidence (C)**	**Satisfaction (S)**	**Dynamic (D)**
Minimum	12	9	9	6	36
Maximum	48	36	36	24	144
p	46,5	33,5	32,0	22,4	134,4
Normalization	$\frac{(p-12)}{0{,}36}$	$\frac{(p-9)}{0{,}27}$	$\frac{(p-9)}{0{,}27}$	$\frac{(p-6)}{0{,}18}$	$\frac{(p-36)}{1{,}08}$
KG	95,83	90,74	85,19	90,97	91,09

The question that presented the largest dispersion of answers was question 1, referring to the initial impression held by students of the dynamic when the dynamic was presented. All of the possible answers were encountered in this question, showing that even before the dynamic began, the students had already created an expectation of ease or difficulty and this expectation varied noticeably between students.

This means of measuring can be applied in other educational activities, simply by adapting the questions utilized (Üççül 2006) for the specific characteristics of the educational activity.

5 CONCLUSIONS

This article presented the application of an educational dynamic with LEGO® pieces, in order to create a type of interactive learning style in the discipline of modeling and discrete-events simulation.

Two important stages can be observed in this dynamic. The first consisted in the elaboration of the conceptual model in IDEF-SIM, in which the students registered the assembly process of the mousetrap by means of a conceptual modeling technique which is already focused on the logic of simulation. In this stage, important elements of simulation were observed, such as entities, locations of transformation, transport, and flow rules.

The second stage consisted of the elaboration of the computational model, which is independent of a specific type of simulation software. In the case of this paper, Promodel 2011® simulation software was used. In this phase, the conversion of the conceptual model into the computational model is highlighted, and the students created a computational model, starting from an actual system that they themselves witnessed.

The ARCS method was used as a means of evaluating the ability of the students to perform abstraction and representation of actual systems in a conceptual and computational model in this paper. The ARCS method evaluated the proposed dynamic on four elements: attention, relevance, confidence, and satisfaction. The evaluation was performed by the IMMS (Instructional Materials Motivational Survey). Each participant answered a questionnaire containing 36 questions. Each answer of the participants was given between 1 (Not true) and 4 (True).

As an aid in evaluating the dynamic, the results of the responses were used to create an indicator, allowing the normalization of the values of the responses and subsequent calculation of their percentage value. The criteria of the ARCS method, with the use of an indicator, could thus be compared from the same base. The criterion ‘attention’ was evaluated the best by the students with 95.83%, followed by ‘satisfaction’ (90.97%), ‘relevance’ (90.74%), and finally, ‘confidence’ with 85.19%. In general, the dynamic reached 91.09%, a score considerably high, which demonstrates the applicability of the dynamic and its utility for teaching discrete-events simulation.

The results of the dynamic proved satisfactory in the process of interactive learning, mostly in what they demonstrate in respect to the construction of the conceptual model. As was noted by the authors of this article, this interactive learning activity of modeling and simulation, facilitated and improved the simulation projects conducted by the students in manufacturing and service companies as a final activity of the discrete-events simulation course.

The research should still, to meet future objectives, make a comparison of the students with and without the use of the dynamic. In addition the measuring instrument used should be applied in other dynamics, for a better evaluation of the instrument. The questionnaire used should be transformed into an online questionnaire and applied to a greater number of students.

ACKNOWLEDGMENTS

The authors of the article thank PADTEC, CNPq, FAPEMIG and CAPES for the research assistance.

REFERENCES

Banks, J. 1998. *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. New York: John Wiley & Sons, Inc.

Bloom, B. S. 1956. *Taxonomy of Educational Objectives: The Classification of Educational Goals*. New York; Toronto; Longmans, Green.

Brooks, R. J., and S. Robinson, 2001. *Simulation with Inventory Control*. Basingstoke: Palgrave Macmillan.

Chapman, A. 2013. Kirkpatrick's Learning and Training Evaluation Theory. Accessed March 20. http://www.businessballs.com/kirkpatricklearningevaluationmodel.html.

Connolly, T. M., M. Stansfield, and T. Hainey. 2007. "An Application of Games-Based Learning Within Software Engineering." *British Journal of Educational Technology* 38:416-428.

Dempsey, J. V,. and R. B. Johnson. 1998. "The Development of an ARCS Gaming Scale." *Journal of Instructional Psychology* 25:215-221.

Garris, R., R. Ahlers, and J. E. Driskell. 2002. "Games, Motivation, and Learning: a Research and Practice Model." *Simulation Gaming* 33:441-467.

Hays, R. T. 2005. *The Effectiveness of Instructional Games: a Literature Review and Discussion*. Orlando: Naval Air Warfare Centerbtraining System Division.

Hernandez-Matias, J. C., A. Vizan, J. Perez-Garcia, and J. Rios. 2008. "An Integrated Modeling Framework to Support Manufacturing System Diagnosis for Continuous Improvement." *Robotics and Computer-Integrated Manufacturing* 24:187-199.

Huang, W., W. Huang, and J. Tschopp. 2010. "Sustaining Iterative Game Playing Processes in DGBL: the Relationship Between Motivational Processing and Outcome Processing." *Computer Education* 55:789-797.

Keller, J. M. 2009. *Motivational Design for Learning and Performance: the ARCS Model Approach*. New York: Springer.

Keller, J. M., and K. Suzuki. 2004. "Learner Motivation and E-Learning Design: a Multinationally Validated Process." *Journal of Educational Media* 29:229-239.

Keller, J. M. 1987. "The Systematic Process of Motivational Design." *Performance Instruction* 26:1-8.

Keller, J. M. 1993. "Manual for Instructional Materials Motivational Survey (IMMS)." Tallahassee, FL.

Kirkpatrick, D. L. 1994. *Evaluating Training Programs – The Four Levels*. San Francisco: Berrett-Koehler Publishers, Inc.

Kleijnen, J. P. C. 1995. "Theory and Methodology: Verification and Validation of Simulation Models." *European Journal of Operational Research* 82:145-162.

Kotiadis, K., and S. Robinson. 2008. "Conceptual Modeling: Knowledge Acquisition and Model Abstraction". In *Proceedings of the 2008 Winter Simulation Conference*, edited by S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, and J. W. Fowler, 951-958. Piscataway, New Jersey: IEEE, Inc.

Law, A. M. 2006. "How to Build Valid and Credible Simulation Models." In *Proceedings of the 2006 Winter Simulation Conference,* edited by L. F. Perrone, F. P. Wieland, J. Liu, B. G. Lawson, D. M. Nicol, and R. M. Fujimoto, 58-66. Piscataway, New Jersey: IEEE, Inc.

Law, A. M., and W. D. Kelton. 2007. *Simulation Modeling & Analysis*. 4th ed. New York: Mcgraw-Hill.

Lindh, J., and T. Holgersson. 2007. “Does Lego Training Stimulate Pupils’ Ability to Solve Logical Problems?” *Computers & Education* 49:1097-1111.

Maehr, M. L. 1976. “Continuing Motivation: An Analysis of a Seldom Considered Educational Outcome.” *Review of Educational Research* 46:443-462.

Mcintyre, D. R., and F. G. Wolff. 1998. “An Experiment With WWW Interactive Learning in University Education.” *Computers & Education* 31:255-264.

Montevechi, J. A. B., F. Leal, A. F. Pinho, R. F. S. Costa, M. L. M. Oliveira, and A. L. F. Silva. 2010. “Conceptual Modeling in Simulation Projects by Mean Adapted IDEF: An Application in a Brazilian Tech Company.” In *Proceedings of the 2010 Winter Simulation Conference,* edited by B. Johansson, S. Jain, J. Montoya-Torres, J. Hugan, and E. Yücesan, 1624-1635. Piscataway, New Jersey: IEEE, Inc.

Pittenger, A, and A. Doering. 2010. “Influence of Motivational Design on Completion Rates in Online Self-Study Pharmacy-Content Courses.” *Distance Education* 31:275-293.

Prensky, M. 2001. *Digital Game-Based Learning*. New York: McGraw-Hill.

Rangel, J. J. A., and A. F. Nunes. 2011. “Use of IDEF-SIM to Document Simulation Models.” In *Proceedings of the 2011 Winter Simulation Conference,* edited by S. Jain, R. R. Creasey, J. Himmelspach, K. P. White, and M. Fu, 1542-1553. Piscataway, New Jersey: IEEE, Inc.

Sargent, R. G. 2009. “Verification and Validation of Simulation Models.” In *Proceedings of the 2009 Winter Simulation Conference*, edited by M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin, and R. G. Ingalls, 162-176. Piscataway, New Jersey: IEEE, Inc.

Üçgül, M. 2006. “The Impact of Computer Games on Students’ Motivation.” M.Sc. thesis, Department of Computer Education and Instructional Technology, School of Natural and Applied Sciences of Middle East Technical University, Ankara, Turkey.

AUTHOR BIOGRAPHIES

JOSÉ ARNALDO BARRA MONTEVECHI is a Titular Professor of the Industrial Engineering and Management Institute at the Federal University of Itajubá in Brazil. He obtained his undergraduate, master’s and doctorate degrees, respectively, in Mechanical Engineering from the Federal University of Itajubá, the Federal University of Santa Catarina, and the Polytechnic School at the University of São Paulo. His research interests include Operational Research, Simulation and Economic Engineering. His e-mail address is montevechi@unifei.edu.br.

FABIANO LEAL is a Professor at the the Industrial Engineering and Management Institute at the Federal University of Itajubá, in Brazil. He holds a bachelor’s and master’s degree, respectively in Mechanical Engineer from the Federal University of Itajubá. He received his Mechanical Engineering doctorate has from the State University of São Paulo. His research interest includes Simulation, Operations Management and Work Study. His email address is fleal@unifei.edu.br.

RAFAEL DE CARVALHO MIRANDA is pursuing a Doctorate in Industrial Engineering from the Federal University of Itajubá, in Brazil. He has a master’s degree in Industrial Engineering and an undergraduate degree in Industrial Engineering which he also received from UNIFEI. His research interests include Simulation, Simulation Optimization and Design of experiments. His email address is mirandaprod@yahoo.com.br.

TÁBATA FERNANDES PEREIRA is a Master’s student in Industrial Engineering at the Federal University of Itajubá, Brazil. She has an undergraduate degree in Information Systems from the Foundation of Education and Research of Itajubá. Her line of research includes discrete-events simulation and knowledge management. Her email is tabatafp@gmail.com.