DISCRETE EVENT SIMULATION FOR DIDACTIC SUPPORT RESOURCE

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ABSTRACT

This paper presents the evaluation of a Discrete Event Simulation model constructed to assist a teacher in the explanation of high school class content. The model was built using the free version of the Arena software after that teacher receives basic training for its use. The model was feasible, both financially and from the results presented. The results showed that the use of the simulation model can provide an increase in learning for students with more difficulty.

1   INTRODUCTION

Several researchers have conducted studies with applications of Discrete Event Simulation (DES) in the field of Simulation Education. Among the many papers that can be found on this subject, two were chosen to illustrate certain aspects. Goldsman (2007) applied DES models as a didactic resource to assist the explanation of Mathematics content for high school students. Rangel and Silva (2011) developed DES models to use as a didactic resource for teaching Telecommunications. In the first study, the focus on using DES models as a support in classes for high school students was the central issue. In the other one, the use of the free version of the Arena software was proposed so that the teacher himself prepares the model and employs it to expose the concepts to be explained to students in classroom. In other words, it would be the application of the model in high school with software free of charge.

Notice that the DES worked as a didactic aid instrument, in both circumstances, so that a teacher could use it according to his need, building a particular simulation model that would be able to assist the explanation of the content to be taught. Also note that this was not repositories, where simulators could be downloaded or even a simulator with a specific purpose being used for skills training. What is being highlighted here is the possibility of using simulation software in order that small models are constructed, by the teacher himself, in a simple and fast way, the same way he can elaborate a spreadsheet or presentation to enrich the explanation of a particular content to be taught in classes.

In fact, what these researchers are presenting goes beyond the traditional applications of DES. Moreover, it can be envisioned the fact of being supporting a sector, in this case, Education, which always needed support tools at low cost. With respect to the use of software versions free or not of costs, it is also added the fact that there is, today, the possibility to use free and open-source Simulators as shown by King and Harrison (2013). This can thus resolve, definitively, the issue of financial viability for small simulation models.

The aim of this paper is to present the evaluation of a DES model built, by a teacher, to assist him in the explanation of a technical course content in high school. The model was built using the free version of the Arena software after the teacher receives basic training in order to use it. This proposal was based on the ease of programming that may also be said "ease of management", of the current software used in the

construction of discrete simulation models. The word management was employed as the teacher himself can develop a simple model, after basic training, without being an expert in computer programming.

2   SIMULATION MODEL CONSTRUCTION

Typically, simulation models are built based on a methodology that guides their construction process. In most cases, these models are developed to be applied to analyzing a specific system. The methodologies were elaborated aiming, in general, the applications to which the respective models are designed.

Thus, for the development of the simulation model of this paper, we proposed the steps shown in Figure 1 that, in general, were determined based on the traditional methodological proposals of Banks *et al*. (2010) and Law (2007). We performed adjustments in order to address the special features surrounding the construction of a simulation model with a didactic purpose. This adaptation aimed to meet the needs of the teacher at the time of building and testing the model.
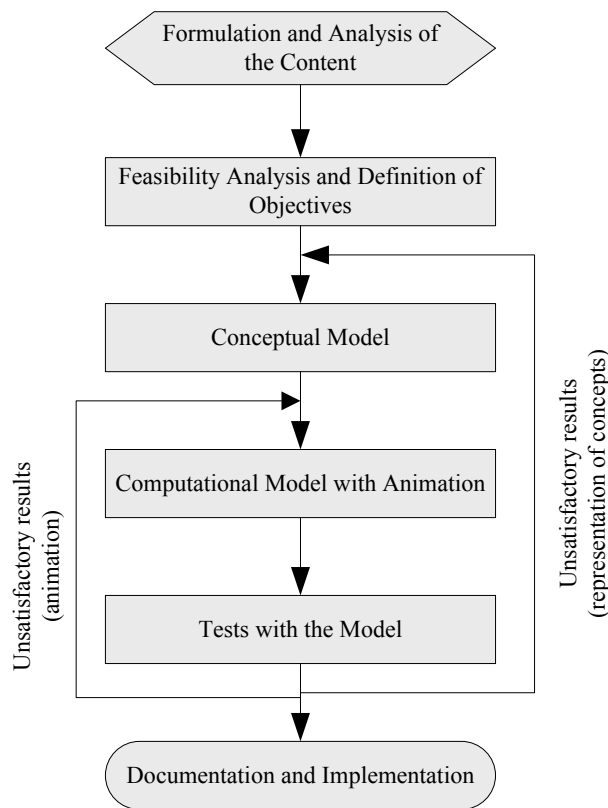
Figure 1: Steps of the construction process of didactic models.

The Formulation and Analysis of the content should be performed from a survey on the need to address the issue through a DES model. Even at this point, it should be checked the nature of the system (discrete or continuous) and, in case of continuous model, if it is possible to discretize it into a DES model.

In the Feasibility Analysis and Definition of Objectives, it is recommended to ask questions about the existence of an appropriate school environment with resources to show the model so that all students can see the effects of the animation. If a teacher intends to build an interactive model, he must be sure there is a room or computer lab in sufficient number to meet the class. Then, in the definition of objectives, the teacher should define the content that will be represented by the model. This delimitation is important

because there are contents with a very extensive and complex approach. When defining the content, errors in modeling are avoided and representation is simpler, facilitating student understanding.

The Conceptual Model aims to translate the concepts of the system that are intended to simulate, making it a structure that will guide and facilitate its transition to the computational model. This is because this technique shows the system context, the integration of the parts involved and the logical format of the model (Sargent 2013).

In the construction of the Computational Model, the teacher will translate the theoretical content modeled in conceptual form into a DES software. As the model has didactic purpose, it is essential to use the animation feature to materialize abstract concepts. Optionally, the use of interactivity in the model can be used providing the student direct interaction with the simulator.

The Test step aims to assess the quality and effectiveness of the model as a pedagogical tool. To test the quality of the model, first it is checked if the construction of the computational model follows the logic of the conceptual model and is also in accordance with the content defined by the teacher. If the analysis is unsatisfactory, it is recommended to return to the conceptual model to trace the logic of content again. The second phase of the quality test is about the animation. For this, the quality of the figures is checked and, also, if the animation represents the content modeled. If quality evaluation is considered unsatisfactory, the teacher shall return to the construction step of the computational model. The teacher may choose to perform tests on day-to-day classroom during implementation, both in the first stage of quality test as in the second one, or rely on the cooperation of other teachers in the area and even their own students. The effectiveness of the model aims to verify the capability of the simulator as a didactic resource. Thus, it is questioned whether the student learns from the model. This questioning is done through assessments of knowledge about the modeled content.

The step of Documentation and Implementation of the model begins with a report comprising the conceptual model and step-by-step construction of the computational model in a DES environment. The Documentation aims to report details of its development, aiming its reproduction by another teacher or a future modification. Soon after, this model can be implemented in classroom by the teacher who built it or by other teachers who teach content simulated in the model. The implementation is what gives meaning to the adaptation of the methodology presented in this work, as it is characterized by the application of the model in classroom as a didactic resource recognized by the tests step.

3   SIMULATION MODEL

This section describes the simulation model built by the teacher himself, using the methodological process presented in the previous section. Initially, the system, object of content to be taught by the teacher, is illustrated. Subsequently, we present the conceptual model of the system and, finally, the didactic simulation model itself.

3.1   System Description

The simulation model developed and evaluated in this work was constructed so as to assist the explanation of the concepts associated with the OSI Reference Model (Open Systems Interconnection). We chose this content due to its wide applications in initial studies on computer networks, and, also, by having relatively abstract concepts that may complicate the explanation in classroom.

According to Tanenbaum (2010), the OSI Model or Reference Standard was created by the ISO (International Standardization Organization) in 1984. The project objective was to facilitate communication among open systems, that is, computer systems that can communicate with other systems. This action should be taken even if the networks have software and / or hardware from different manufacturers.

That standard was subdivided into 7 Layers that represent the functions involved in the communication between two hosts, which are in different networks of computers. Figure 2 illustrates the OSI Reference Standard.

Layer

Name of unit
exchanged

7	Application	Application protocol	Application	Data - APDU
6	Presentation	Presentation protocol	Presentation	Data - PPDU
5	Session	Session protocol	Session	Data - SPDU
4	Transport	Transport protocol	Transport	Segment - TPDU
3	Network	Network protocol	Network	Packet
2	Data Link	Data Link protocol	Data Link	Frame
1	Physical	Physical protocol	Physical	Bit

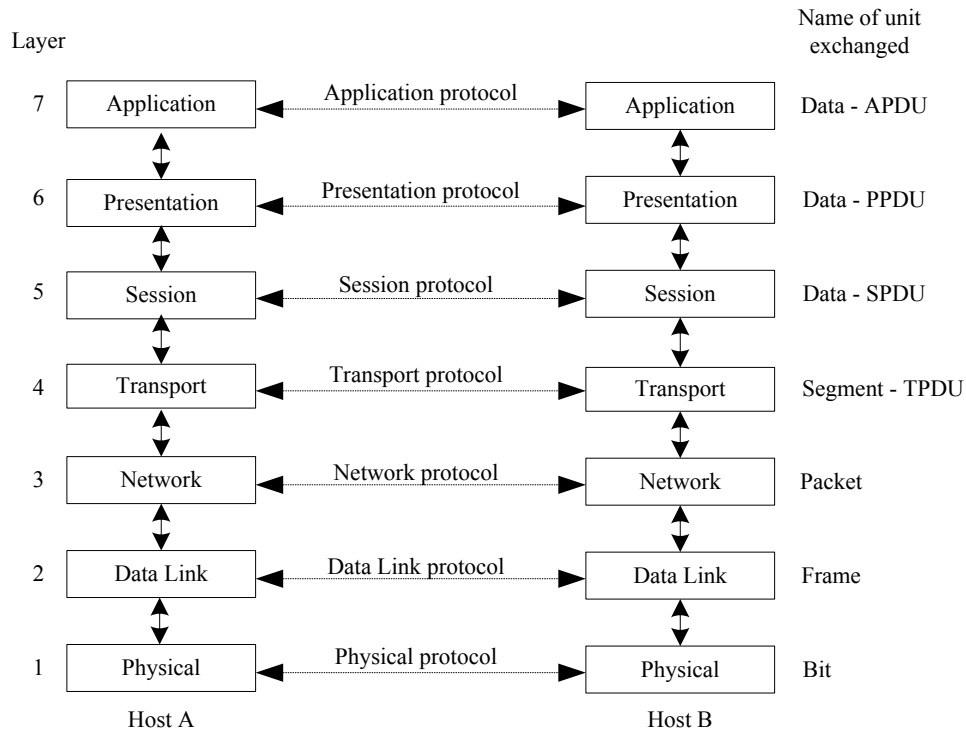Host A   Host B

Figure 2: The 7 Layers of the OSI Reference Standard.

Each Layer has a specific function so that the information is processed and reaches the end user, as follows:

1. The Physical Layer handles the information at the level of bits, amplifying, interpreting and repeating the signal. Hub, modem and cable are device examples of this layer.
2. The Data Link Layer handles the information at the level of frame, adding MAC address (Media Access Control) and error checkers. The switch and bridge are device examples that operate at this layer.
3. The Network Layer handles the information as package or datagrams, entering and identifying the IP address - Internet Protocol of origin and destination. The router is an equipment example that works in this layer.
4. The Transport Layer handles the information at the level of tracking, transporting packets and datagrams to the destination.
5. The Session Layer handles the information at the level of data and is responsible for establishing and managing session between two hosts, deciding, for example, if the data exchange is Half or Full Duplex.
6. The Presentation Layer handles the information as data, which are represented in the proper format for the environment, equipment or users. ASCII, JPEG and MPEG are examples of representation codes of this layer.
7. The Application Layer handles the information at the level of data, providing services directly to the final user via protocols such as HTTP, DNS, and FTP.

The objective of the simulation model was to illustrate the main concepts related to this communication and be able to, thereby, assist the teacher during the explanation of the content. In

addition, the students should use the model outside of the classroom environment to better fix the learned content.

3.2   Conceptual Model

Based on the steps described from the elements presented in Figure 2, the simulation model was built, by the teacher of the discipline, to be used in a class about the OSI Reference Standard. Figure 3 shows the simulation model mentioned. The model is described in IDEF-SIM language. Such language was proposed by Montevechi *et al*. (2010) and can be used, in general, for a conceptual model of simulation models in different applications. Moreover, in Appendix A, description of the elements contained in the simulation model can be found.

The construction step of the computational model with animation began with the choice of 14 Arena software in student version, offered free of cost by the product vendor. This software enables the construction of simulation models free of charge, being also of easy reach. To build the model, the teacher had 20 hours of basic training with the software (similar to the training offered by the supplier) and took 16 hours to make it.

The most common modules of the software structure were employed. From the Basic Process template, we used the Create, Dispose, Process, Decide, Batch, and Assign. From the Advanced Process, we applied the ReadWrite for interacting with data in the model. Now, in relation to the Advanced Transfer template, Route and Station were used to facilitate the visualization. The Create module was used as input of information. The Assign was used in the creation of entities represented in the animation as: bits of input signal; frames; packages; datagrams; data transmitted in Full and Half Duplex; representation codes of text, videos and photos; as well as HTTP, FTP and DNS services. The Station was used in the interconnection between layers and supporting the part of the model animation. The Router sends the information from the Stations of each layer to the next, besides allowing the animation of the model. The Process is used to perform functions such as amplify the signal; define bits "0" and "1"; form frames; define MAC; insert error control; form packages; define IP; control flow; manage session; represent texts, photos and videos; and deliver HTTP, FTP and DNS services. Finally, the Dispose terminates the process of information transference.

Figure 3 shows the entity Information (D1), at the entrance of the system, which will be amplified by process (F1), in the Layer 1, and will have its binary format defined by process (F2).

The bits of the Layer 1 will be transported by (M1) to the Layer 2, which will form frames from the process (F3), insert, in this frame, the MAC addresses of origin and destination using the process (F4), and add control techniques of error in the process (F5). With the frame of Layer 2 complete, the error inspection process will be executed (F6). As a result of this inspection, the frame will be discarded (F8), and right frames will follow their trajectory, obeying the queue (F7) for access to the middle up to the next layer.

The frames of Layer 2 will be transported by (M2) up to Layer 3 where they will go through the packaging process (F9), IP (F10) address definition and routing (F11) based on the type of service. According to the service definition, this package can be forwarded to the connection-oriented service (F12), from where the virtual circuit package will leave (E2), or may be directed to the connectionless service (F13) from where the datagram will leave (E3).

Layer 4 will receive ~~of~~ from M3 the entities E2 and E3, which will go through the Decisor of transport of User Datagram Protocol (UDP) or Transmission Control Protocol (TCP) (F14), leading the datagrams (E3) to the UDP transport (F15). The packages (E2) will go through the processes of TCP such as the flow control (F16), sequence control and error (F17) and discard packages with errors through (F18).

Layer 5 that receives the data via M4 and through the session control F19 will decide if the communication between two devices will be Half (F20) or Full Duplex (F21) according to the flow of the network (preferably Full Duplex).

Layer 6 receives the data of the Layer 5 via the M5 and will translate the dataset to its original format (F22) by using the still images compression code - Joint Photographic Experts Group (JPEG) (F25) of the moving picture compression code - Moving Picture Experts Group (MPEG) (F24) or through the American Standard Code for Information Interchange - American Standard Code for Information Interchange (ASCII) (F23) in case of representing texts.

Layer 7 will take the information (M6), represented by Layer 6, and deliver to the destination through the appropriate server using an user service identifier (F26), which may be the server of Hypertext transfer protocol - Hypertext Transfer Protocol (HTTP) (F27) to communicate with the web, file transfer protocol server - file Transfer Protocol (FTP) (F28) or a server of domain names - Domain Name System (DNS) (F29).
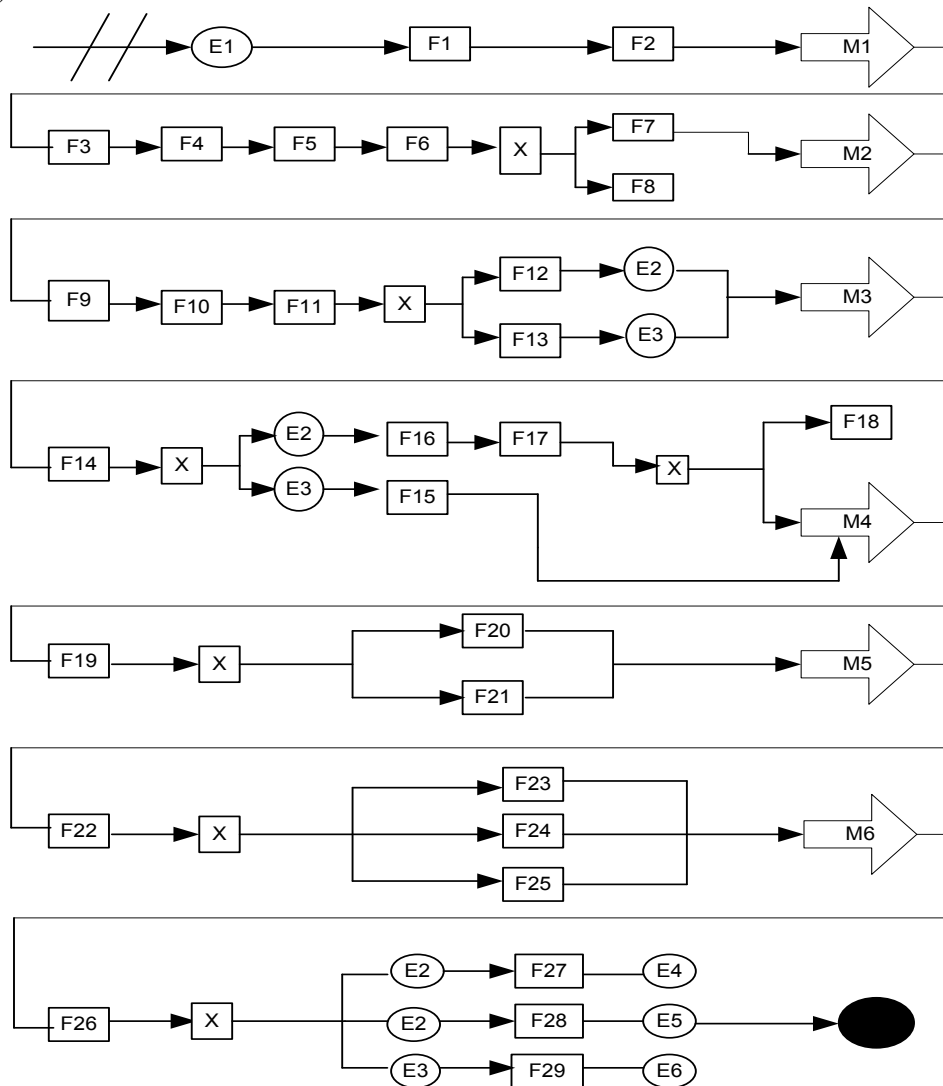
Figure 3: Conceptual Model on the OSI Reference Standard.

3.3 Didactic Simulation Model

The computer used to develop the computational model was a laptop with the following features: Windows 7, Intel Core i5 processor, 2.4 GHz, 14-inch LED display and a resolution of 1366 x 768 pixels,

RAM memory of 4096 MB DDR3 and HD 500 GB. It was not necessary to use any additional resource in the development of the model.

Table 1 describes the main features of the computational model presented in this work:

Table 1: Characteristics of the simulation model.

Characteristics	Discrete Event Simulation Software
Simulation software	ARENA 14
Developer	Teacher of the discipline
Type of license	Free (Free version of costs)
Interactivity	Allows
Change	Allows
Difficult degree of programming	Low
Time of development	15 hours
Hours of training	20 hours

Table 1 shows that the simulation model was developed by the teacher of the discipline using the free version of Arena. The model built in Arena can also be modified at any time. The degree of difficulty for its construction was considered low because the teacher who conducted the programming had a 20 hour-training and, even so, was able to develop a didactic and interactive model with 15 hours of programming.

The animation of the model was divided into two parts for better visualization of the concepts. The first part represents the functions, equipment and protocols of the first four layers of the OSI model. The second is the functions and protocols present in the last three layers.

Figures 4 and 5 show an instant of the first and second parts of the animation respectively.
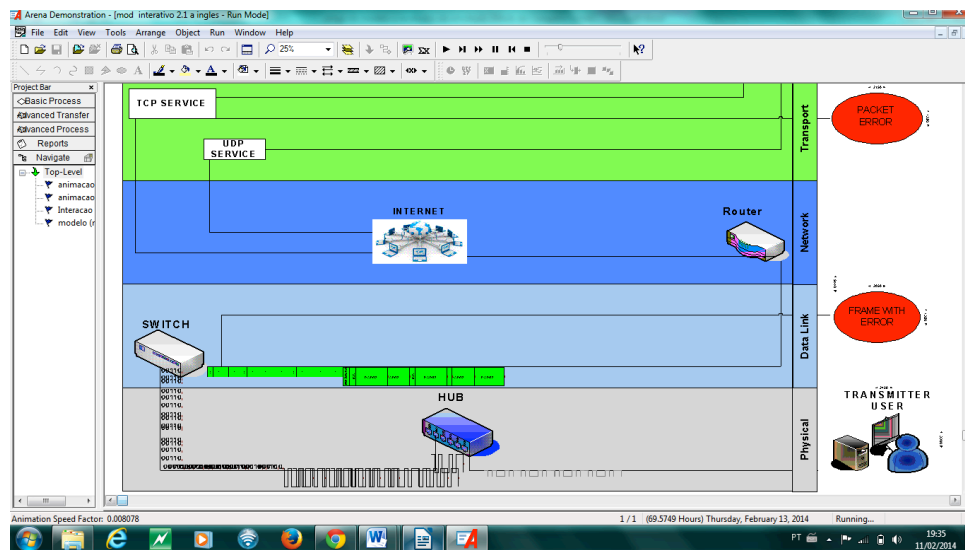

Figure 4: Animation instant of the first part of the simulation model.

Figure 4 shows the performance of the switch in the creation of frames at the Data Link layer, which are sent to the Network Layer, where they transform into packages and datagrams when passing through the router. The Transport Layer, through the connectionless-oriented service, sends the datagrams through

the UDP protocol. The packages are transported by connection-oriented service through the TCP protocol.
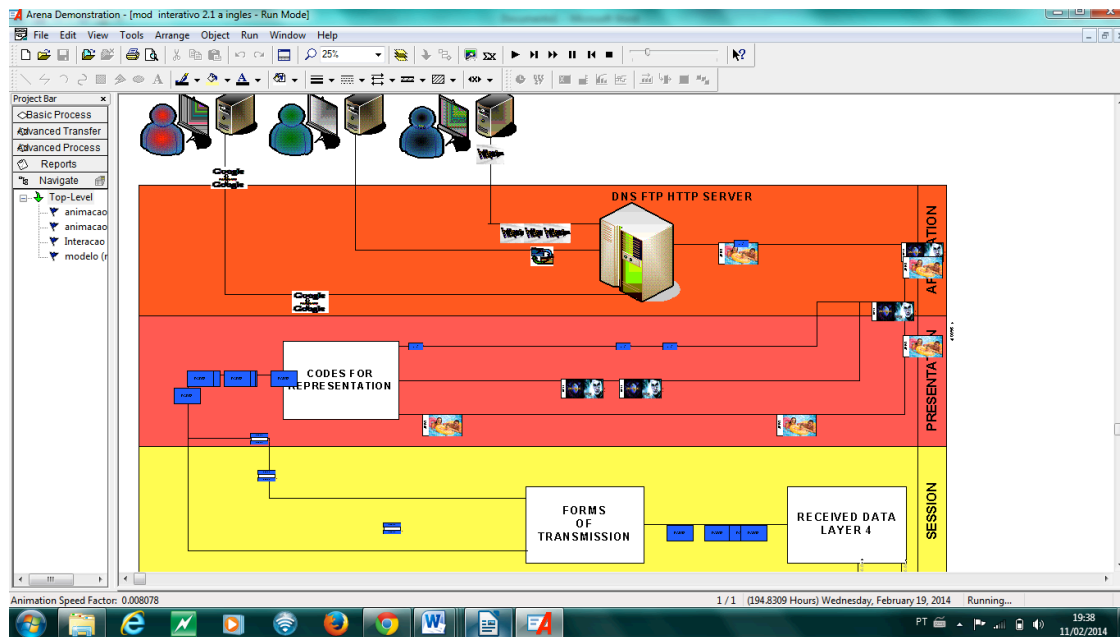

Figure 5: Animation instant of the second part of the simulation model.

Figure 5 shows the data being received by the Session Layer and transmitted in Full Duplex mode to the Presentation Layer. In the Presentation Layer, the data are transformed into text, images and video, through representation codes. At the Application Layer, these representations are received and sent to the server, which delivers the information to the final user via HTTP, FTP and DNS protocols.

The model also offers the feature of interactivity, allowing the student to modify the amount of inserted bits. This modification generates a change in the time of departure of the data in the model. This process helps the student to understand the concept of flow control in the network.

4   EVALUATING THE USE OF SIMULATION MODEL IN CLASSROOM

The evaluation of learning with the use of the simulation model as a didactic resource was conducted with a sample of 148 students. These students came from technical courses in high school, from areas of Electronics, Telecommunications and Informatics, of three different schools, two public institutions and a private one. They are located in the municipality of Campos dos Goytacazes, Rio de Janeiro State, Brazil. The classes and assessments were conducted during the months of August and September 2013.

The evaluation consisted of nine multiple-choice questions structured based on the degree of difficulty, that is, three easy questions, three medium and three difficult. The entire evaluation was made on the content taught in classroom, where the teacher had the support of the simulator according to the need.

The easy questions addressed the number of layers and their ordering besides the encapsulation and decapsulation processes of information through these layers. The questions considered medium asked about the functions of the OSI model, the format of the PDU at each level and the performance of protocols in each layer. Difficult issues were related to the functions performed by each layer on the flow control and on the equipment associated to the model levels.

To verify the accuracy rate, it was considered the profile of students according to the average of their grades in disciplines related to the content represented by the simulation model and, also, in accordance to

the averages of all subjects in the course (coefficient of performance - CP). With this in mind, the analysis concerning three profiles of students were performed, that is, students with averages below six, with averages equal to six and lower than eight, and those with averages equal to or greater than eight. Firstly, the analysis of the student learning was taken from the use of descriptive statistics as the results shown in Figures 6 and 7.

Figure 6 shows the accuracy rate of students according to the didactic method (four groups or treatments) and according to the grade obtained in the discipline of the current semester.
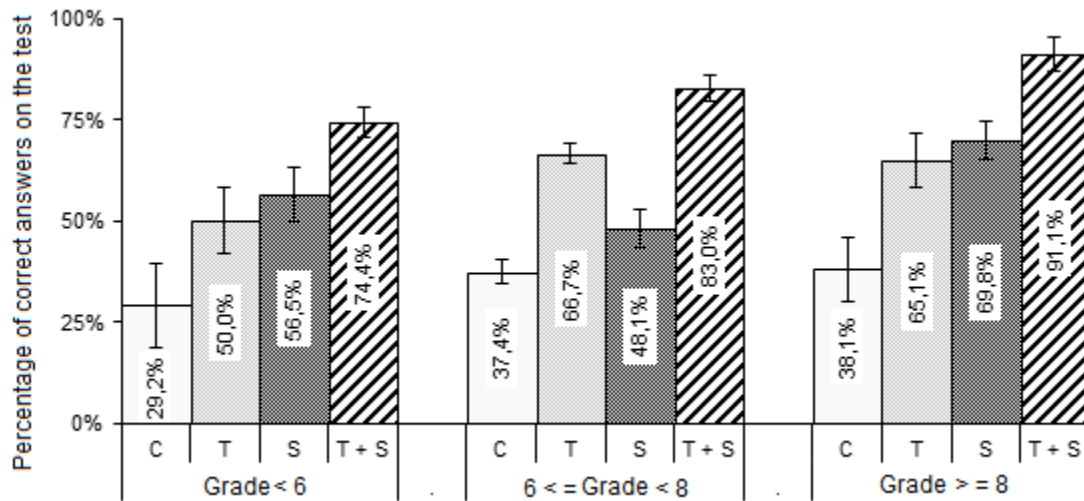

Figure 6: Accuracy rate according to the didactic method and in accordance with the grade in the discipline, where: C: control group - students who were not subjected to any method of exposing the contents, T: group only with theoretical class, S: group only with simulator class, and S + T: group with both theoretical and simulator classes.

Figure 6 shows that, in students with a grade less than 6 on content-related discipline, the accuracy rate to those who had classes with the two didactic methods (T + S) was 74.4%. In the group of students with an average between 6 and 8, the use of the theory plus the simulator increased the accuracy rate to 83% while, in the isolated use of the theory, the accuracy rate was 66.7%. On students with a grade equal to or greater than 8, the use of the didactic simulator added to the theory resulted in the accuracy rate of 91.1%. These results show that the interaction between the two didactic methods were most significant in students averaging less than 6 because, with the insertion of the simulator during theoretical classes, these students would gain averages approximately 7.4. Moreover, it can also be observed that the individualized use of the simulator was more efficient than the theory for students of low averages and students of high average, since, in the group with grade below 6, the theory provided an accuracy rate of 50% against 56.5% of the simulator. For students having averages above 8, the theory provided 65.1% of accuracy rate while the isolated use of the simulator resulted in 69.8%.

Figure 7 shows the performance of students in accordance with the didactic method used and according to the CP of the student in the course.

According to Figure 7, it is possible to note that, in all three groups of students separated by CP, using the simulator with the theory was more efficient than the two methods isolated. Moreover, in the first group, where students had CP lower than 6, the class with the two methods provided an accuracy rate of 86.1%. In the group of students with CP between 6 and 8, this rate was 80.9%. Now, students with CP equal to or greater than 8, the accuracy rate was 88.9%.

Analyzing the separate use of the two methods, the theory had better performance in the group with an average between 6 and 8, with a rate of success of 61.7% against 51.2% in the use of the simulator, and in the group with CP equal to or greater than 8, with 69.1% accuracy with theoretical class versus 63% with class with the simulator. The simulation was more efficient than the theory in students with CP less than 6 because it resulted in a 59% accuracy rate against 47% of the theory.
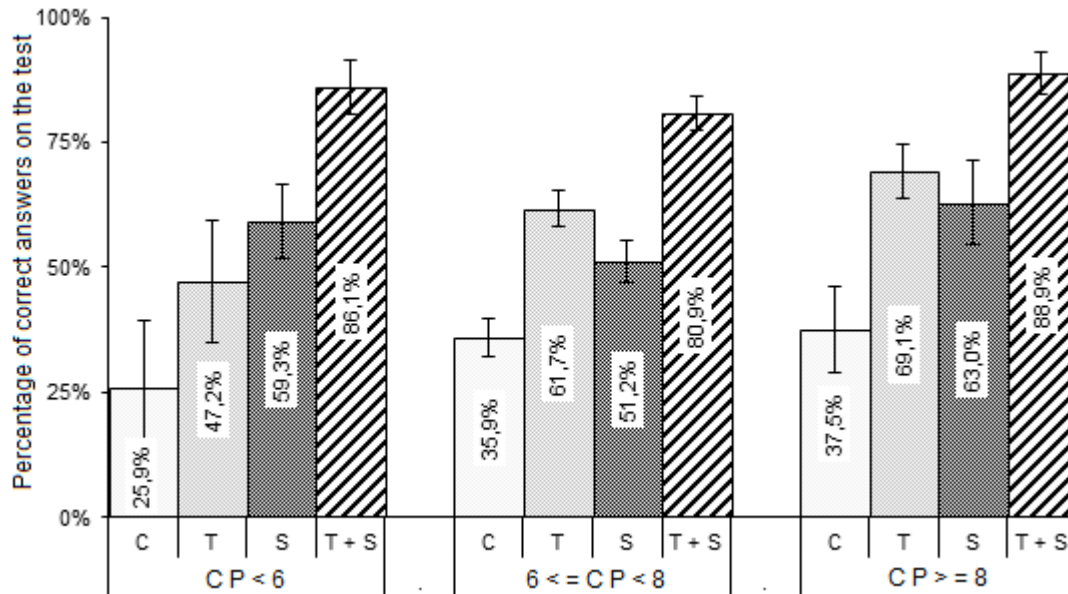

Figure 7: Accuracy rate in accordance with the didactic method and the CP in the course.

Observing and comparing the performance of students concerning their CPs, note that students with averages lower than 6 had the highest increase because their grades would be equivalent to 8.6 after the application of the simulator together with the theory.

5   CONCLUDING REMARKS

The present study showed the application of a simulation model used as a didactic resource by a teacher. The model was designed and built by the teacher himself after receiving basic training on the use of software for wide application in the construction of simulation models. Such teacher used the free version of costs of this software offered by the supplier. The proposed pedagogical tool (simulation model) proved to be feasible both from a financial perspective as by the results presented. The analysis aimed to evaluate the use of the simulation model in an ordinary class.

Thus, the results showed that the use of the simulation model allowed an increase in student learning having lower averages. Specifically, what happened was that students with averages below 6 had the closest grades to the students of average equal or above 8 when performed simulations on the content taught. This indicated that the use of this determined didactic resource has the potential to improve the academic performance.

The results of this study indicate a favorable aspect in the implementation of DES as a didactic resource. However, further researches should be conducted with a larger number of samples in relation to both students and teachers.

ACKNOWLEDGMENTS

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Appendix A: Description of Elements Contained in Simulation Model.

Item	Description	Parameters	Item	Description	Parameters
E1	Entrance Information	Constant; 1 at a time; Max. 100	F16	Control Flow of TCP Packets	Triangular; 1 at a time; min. 0,5; max. 1.5
E2	TCP Packet	Constant; 1 at a time;	F17	Control Errors and Sequences in the TCP Packets	Triangular; 1 at a time; min. 0,5; max. 1.5
E3	UDP Datagram	Constant; 1 at a time	F18	Discard Packets with Errors	Triangular; 1 at a time; min. 0,5; max. 1.5
E4	Data from Server FTP	Constant; 1 at a time	F19	Manage and Control Session	2-way by chance; 80%
E5	Data from Server HTTP	Constant; 1 at a time	F20	Session Half	Triangular; 1 at a time; min. 0,5; max. 1.5
E6	Data from Server DNS	Constant; 1 at a time	F21	Session Full	Triangular; 1 at a time; min. 0,5; max. 1.5
F1	Amplification	Triangular; 1 at a time; min. 0,5; max. 1.5	F22	Represent Data Based on Format	N-way by chance; 40%, 30%, 30%
F2	Define bit "1" and bit "0"	Triangular; 1 at a time; min. 0,5; max. 1.5	F23	Represent Text through ASCII	Triangular; 1 at a time; min. 0,5; max. 1.5
F3	Form Frames		F24	Represent Video through MPEG	Triangular; 1at a time; min. 0,5; max. 1.5
F4	Define MAC	Triangular; 1 at a time; min. 0,5; max. 1.5	F25	Represent Photo through JPEG	Triangular; 1at a time; min. 0,5; max. 1.5
F5	Insert Error Control	Triangular; 1 at a time; min. 0,5; max. 1.5	F26	Identify the Service	N-way by chance; 50%, 25%, 25%
F6	Inspect Frames	Triangular; 1 at a time; min. 0,5; max. 1.5	F27	Service of HTTP	Triangular; 1 at a time; min. 0,5; max. 1.5
F7	Access Queue to the Means	*Delay* 2 seconds	F28	Service of FTP	Triangular; 1 at a time; min. 0,5; max. 1.5
F8	Discard Frame with Error	Triangular; 1 at a time; min. 0,5; max. 1.5	F29	Service of DNS	Triangular; 1at a time; min. 0,5; max. 1.5
F9	Form Packets	Triangular; 1 at a time; min. 0,5; max. 1.5	M1	Send Bits to Layer 2	Route time 30 seconds
F10	Define IP	Triangular; 1 at a time; min. 0,5; max. 1.5	M2	Send Frames to Layer 3	Route time 2 seconds
F11	Make Routing Based on Service	2-way by chance; 75%	M3	Send Packets to Layer 4	Route time 10 seconds
F12	Service Oriented to Connection	Triangular; 1 at a time; min. 0,5; max. 1.5	M4	Send Data to Layer 5	Route time 10 seconds
F13	Service not Oriented to Connection	Triangular; 1 at a time; min. 0,5; max. 1.5	M5	Send Data to Layer 6	Route time 10 seconds
F14	Define Protocol According to F12/ F13	Triangular; 1 at a time; min. 0,5; max. 1.5	M6	Send Data to Layer 7	Route time 10 seconds
F15	Deliver the UDP Datagrams	Triangular; 1 at a time; min. 0,5; max. 1.5	M6	Send Data to Layer 7	Route time 10 seconds